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INSTRUCTION MANUAL

KEPCO®
THE POWER SUPPLIER™

KEPCO, INC. • 131-38 SANFORD AVENUE • FLUSHING, NY 11352 USA
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KEPCO

BOP

BIPOLAR OPERATIONAL POWER SUPPLIES

Please record the equipment nameplate serial number in the space provided.

Model BOP 100-1M

Serial No. . . . . .

instruction manual

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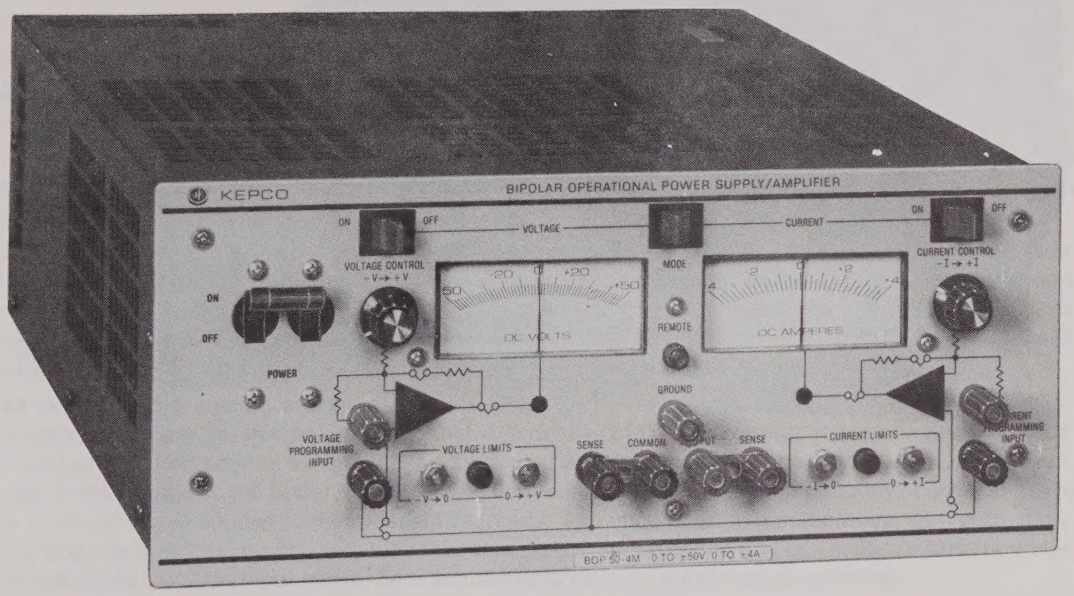


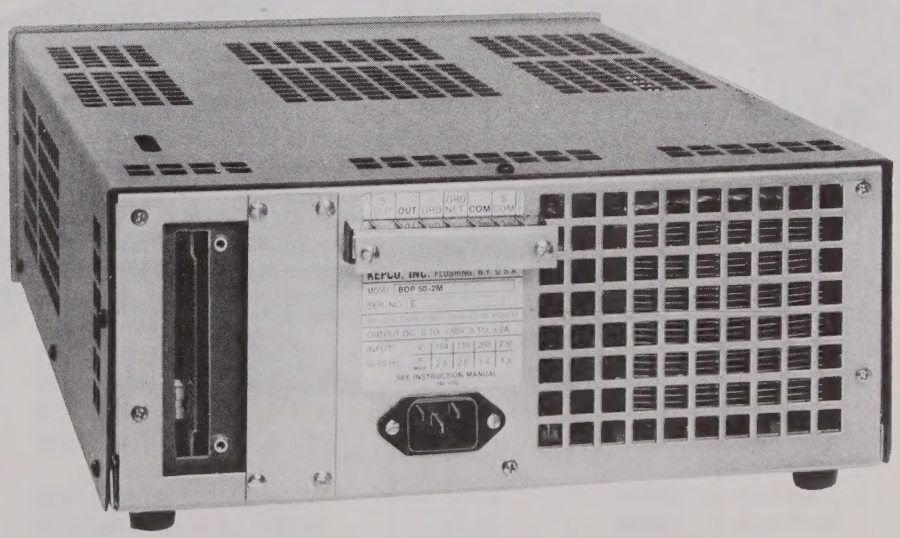
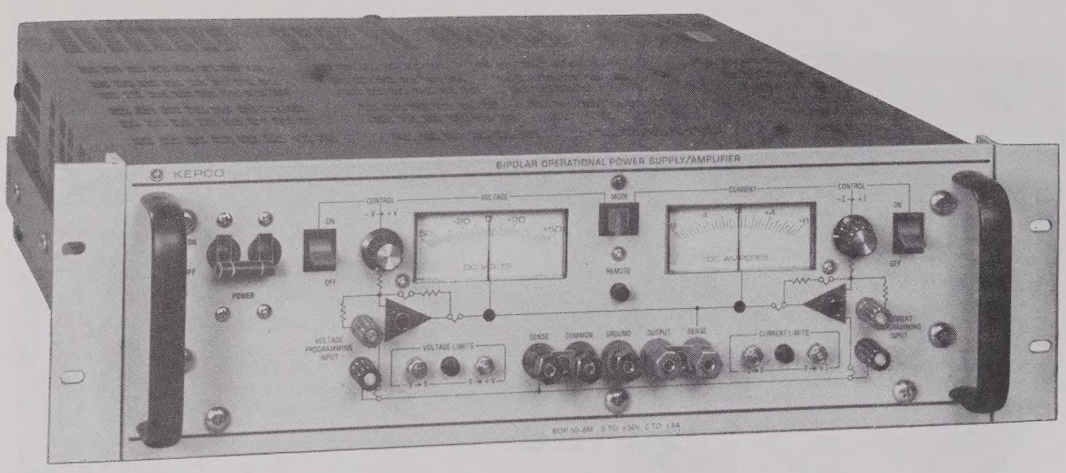


FIG. 1-1A KEPCO BIPOLAR OPERATIONAL POWER SUPPLY (¾ RACK BOP)



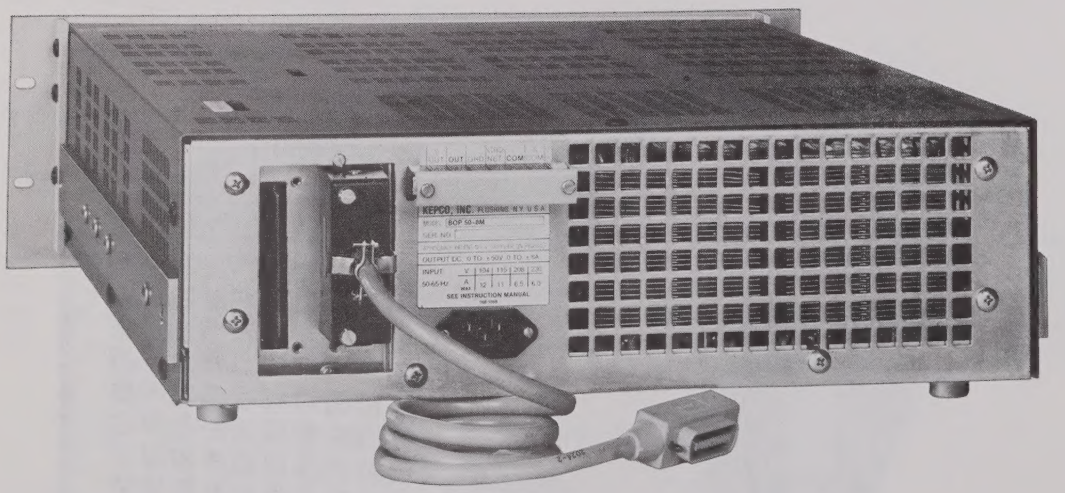


FIG. 1-1B KEPCO BIPOLAR OPERATIONAL POWER SUPPLY (FULL-RACK BOP)

SECTION I — INTRODUCTION

1-1 SCOPE OF MANUAL

1-2 This manual contains instructions for the installation, operation and maintenance of the BOP series of Bipolar, operational power supplies, manufactured by Kepco Inc., Flushing, New York, U.S.A.

1-3 GENERAL DESCRIPTION

1-4 The Kepco series BOP Bipolar Power Supplies are fully dissipative, linear stabilizers for laboratory and systems applications. The BOP is an all solid-state design, featuring IC operational amplifiers in the control circuit section and silicon power transistors mounted on special fan-cooled heat sinks in the complementary power stage.

1-5 The BOP has two bipolar control channels (voltage or current mode), selectable and individually controllable either from their front panel controls, or by remote signals. Each of the principal control channels is protected by bipolar limit circuits. In these limit circuits the positive and negative current or voltage limit points can be manually set or remotely programmed simultaneously or individually. Automatic crossover between each principal control channel and its associated limit channel is provided.

1-6 All control and bounding channels are connected to the complementary output stage via an "EXCLUSIVE OR" gate, so that only one channel is in control of the BOP output at any one time. The BOP output can be programmed over its full output range by a ± 10 volt signal applied to either one of the inputs to the voltage or the current channel. The limit control channels can be remotely controlled by a 0 to + 10 volt signal applied to their respective inputs. Two uncommitted preamplifiers, with both, inverting and non-inverting inputs available at the rear programming connector, can scale any programming source to the required input levels. Zero adjustments for both amplifiers are provided.

1-7 The BOP is a fast programmable power supply with considerable bandwidth and thereby sensitive to reactive loads. The dynamic specifications, given in Table 1-3, are valid for resistive loads only.

1-8 ELECTRICAL SPECIFICATIONS, GENERAL

A) INPUT SOURCE REQUIREMENTS: 95 to 113V a-c ***or*** 105 to 125V a-c ***or*** 190 to 226V a-c ***or*** 210 to 250V a-c, 50 to 65 Hz, selectable (refer to Section II, FIG. 2-3). The primary circuit is protected by a circuit breaker, effective at all input voltages. Input current and power are listed in the table below.

B) OPERATING TEMPERATURE RANGE: 0°C to +55°C.

C) STORAGE TEMPERATURE RANGE: −40°C to +85°C.

D) COOLING: By built-in, sealed bearing fans, exhausting to the rear of the BOP.

E) ISOLATION FROM GROUND: The BOP circuitry, its output and programming terminals have no d-c connection to the chassis. The COMMON terminal of the BOP can be operated up to 500 volts (d-c or peak) off a-c ground. The common mode current (leakage from output to ground) is less than 50 μA (rms) or 5 mA (p-p) at 115V a-c power input, 60 Hz.

MODEL	OUTPUT POWER	MAX. INPUT CURRENT	MAX. INPUT POWER	PACKAGE
BOP 50-2M	100W	2.9A	270W	¾ Rack
BOP 100-1M	100W	2.9A	270W	¾ Rack
BOP 20-10M	200W	5.5A	540W	¾ Rack
BOP 36-6M	200W	5.1A	490W	¾ Rack
BOP 50-4M	200W	4.8A	450W	¾ Rack
BOP 72-3M	200W	5.1A	470W	¾ Rack
BOP 100-2M	200W	4.8A	450W	¾ Rack
BOP 200-1M	200W	4.8A	450W	Full Rack
BOP 20-20M	400W	11.2A	1115W	Full Rack
BOP 36-12M	400W	10.7A	1050W	Full Rack
BOP 50-8M	400W	9.6A	1000W	Full Rack
BOP 72-6M	400W	10.9A	1085W	Full Rack
BOP 100-4M	400W	9.2A	885W	Full Rack

Approximate maximum input current and power at 125V a-c, 60Hz.

1-9 ELECTRICAL SPECIFICATIONS, PERFORMANCE

A) OUTPUT RANGES: See Table 1-1

MODEL	d-c OUTPUT RANGE E_o max.	I_o max.	CLOSED LOOP GAIN VOLTAGE CHANNEL G_V (V/V)	CURRENT CHANNEL G_I (A/V)	OUTPUT IMPEDANCE VOLTAGE MODE SERIES R	SERIES L	CURRENT MODE SHUNT R	SHUNT C
100 WATT								
BOP 50-2M	± 50V	± 2A	5.0	0.2	0.5 mΩ	100μH	50 kΩ	0.05μF
BOP 100-1M	±100V	± 1A	10.0	0.1	2.0 mΩ	200μH	100 kΩ	0.05μF
200 WATT								
BOP 20-10M	± 20V	±10A	2.0	1.0	40 μΩ	50μH	20 kΩ	0.1μF
BOP 36-6M	± 36V	± 6A	3.6	0.6	120 μΩ	50μH	36 kΩ	0.1μF
BOP 50-4M	± 50V	± 4A	5.0	0.4	0.25 mΩ	100μH	50 kΩ	0.05μF
BOP 72-3M	± 72V	± 3A	7.2	0.3	0.48 mΩ	200μH	72 kΩ	0.05μF
BOP 100-2M	±100V	± 2A	10.0	0.2	1.0 mΩ	200μH	100 kΩ	0.05μF
BOP 200-1M(1)	±200V	± 1A	20.0	0.1	4.0 mΩ	600μH	200 kΩ	0.03μF
400 WATT								
BOP 20-20M	± 20V	±20A	2.0	2.0	20 μΩ	50μH	20 kΩ	0.2μF
BOP 36-12M	± 36V	±12A	3.6	1.2	60 μΩ	50μH	36 kΩ	0.2μF
BOP 50-8M	± 50V	± 8A	5.0	0.8	125 μΩ	100μH	50 kΩ	0.15μF
BOP 72-6M	± 72V	± 6A	7.2	0.6	240 μΩ	200μH	72 kΩ	0.1μF
BOP 100-4M	±100V	± 4A	10.0	0.4	500 μΩ	200μH	100 kΩ	0.1μF

(1) Same size as 400W models

TABLE 1-1 OUTPUT RANGE AND OUTPUT IMPEDANCE

B) OUTPUT EFFECTS: See Table 1-2.

STATIC SPECIFICATIONS

INFLUENCE QUANTITY		OUTPUT EFFECTS(1) VOLTAGE MODE TYPICAL	MAXIMUM	CURRENT MODE TYPICAL	MAXIMUM	PREAMPLIFIER OFFSETS ΔE_{io}	ΔI_{io}	REFERENCE ± 10V
SOURCE VOLTAGE (min.-max.):		<0.0005%	0.001%	<0.002%	0.005%	<5μV	<1nA	<0.0005%
LOAD (No Load—full load):		<0.001%	0.002%	<0.5mA	1mA	—	—	<0.0005%
TIME (8-hour drift):		<0.005%	0.01%	<0.01%	0.02%	<20μV	<1nA	<0.005%
TEMPERATURE, per °C:		<0.005%	0.01%	<0.01%	0.02%	<20μV	<1nA	<0.005%
RIPPLE and NOISE:(2)	rms	<1mV	3mV	<0.01%	0.03%	—	—	—
	p-p(3)	<10mV	30mV	<0.1%	0.3%	—	—	—

(1) Output effects, expressed as a percentage, are referred to the maximum rated output voltage or current.

(2) Measured with the common terminal grounded so that the common mode current does not flow through the load.

(3) Peak-to-peak ripple is measured over a 20 Hz to 10 MHz bandwidth.

TABLE 1-2 OUTPUT EFFECTS, OFFSETS AND REFERENCE SPECIFICATIONS.

C) The BOP ***output effects,*** in response to the tabulated variations in the INFLUENCE QUANTITIES, are given in Table 1-2 for the built-in input and feedback resistor values of the voltage and current channel preamplifiers. The tabulated OFFSET VALUES (see Table 1-2) may be used to calculate the BOP ***output effects*** if the BOP voltage or current channel is remotely programmed and different values for the feedback resistors (R_f) and the input resistors (R_i) are used. In this case, the tabulated preamplifiers offsets and the values of the feedback and input resistors are combined in an "Error Equation", which represents the "Worst Case" output effect for the application at hand:

VOLTAGE MODE: $\Delta E_o = G_V [\pm \Delta E_{io} (1 + R_f/R_i) \pm \Delta I_{io} R_f \pm \Delta E_{ref}]$

CURRENT MODE: $\Delta I_o = G_I [\pm \Delta E_{io} (1 + R_f/R_i) \pm \Delta I_{io} R_f \pm \Delta E_{ref}]$

NOTE: Variations in the value of the feedback and input resistors are considered secondary effects in the Error Equation. See Section IV of this manual for the derivation of the Error Equation.

Where: ΔI_o = Total Output Current Change.
G_V = Closed Loop Gain, Voltage Mode, (see Table 1-1).
G_I = Closed Loop Gain, Current Mode, (see Table 1-1).
ΔE_o = Total Output Voltage Change.
ΔE_{ref} = Change in the Voltage Reference.
ΔE_{io} = Change in Offset Voltage.
ΔI_{io} = Change in Offset Current.
R_f = External Feedback Resistor.
R_i = External Input Resistor.

E) PEAK POWER: $\pm$ (E_o max) ($I_{o\ max}$), **Where:** E_o max. = Maximum rated BOP output voltage.
I_o max. = Maximum rated BOP output current.

F) DYNAMICS: The typical dynamic responses of the BOP output are tabulated in Table 1-3 in both the time domain (Output response to a step program) and in the frequency domain (bandwidth) for large and small signals.

MODEL	BANDWIDTH (d-c tof$_{-3dB}$) KHz (minimum) Mode		RISE & FALL TIME 10%-90% µsec (maximum) Mode		LARGE SIGNAL FREQUENCY (min) RESPONSE, KHz Mode		SLEWING RATE (minimum) Mode		RECOVERY STEP LOAD µsec (maximum) Mode	
	V	I	V	I	V	I	V	I	V	I
100 WATT										
BOP 50-2M	18	12	20	30	17	13	5V/µsec	0.15A/µsec	25	10
BOP 100-1M	18	11	17	22	18	11	11V/µsec	70mA/µsec	40	25
200 WATT										
BOP 20-10M	18	6	20	60	17	7	2V/µsec	0.4A/µsec	80	20
BOP 36-6M	16	13	20	27	15	14	3V/µsec	0.5A/µsec	50	35
BOP 50-4M	23	14	14	25	15	11	4.5V/µsec	0.25A/µsec	40	30
BOP 72-3M	20	15	18	26	17	12	10V/µsec	0.15A/µsec	30	30
BOP 100-2M	22	15	18	26	17	12	10V/µsec	0.15A/µsec	30	30
BOP 200-1M	3.8	1.8	70	150	3.5	1.8	4V/µsec	10mA/µsec	150	120
400 WATT										
BOP 20-20M	9.5	10	35	35	8	10	1V/µsec	1.25A/µsec	100	75
BOP 36-12M	20	10	16	30	19	10	4V/µsec	0.75A/µsec	50	30
BOP 50-8M	24	10	14	35	24	11	7.5V/µsec	0.5A/µsec	40	30
BOP 72-6M	19	9.5	18	40	20	11	9V/µsec	0.4A/µsec	50	20
BOP 100-4M	18	14	22	30	16	10	10V/µsec	0.25A/µsec	40	30

TABLE 1-3 DYNAMIC SPECIFICATIONS, BOP 100W, BOP 200W AND BOP 400W MODELS.

1-10 MISCELLANEOUS FEATURES

A) OUTPUT RANGE: The BOP can be locally (front panel) adjusted, or remotely programmed, from (−)100% to (+)100% of its specified d-c voltage and current range. The Class A bipolar output stage permits operation as either a SOURCE or a SINK. (See FIG. 1-2).

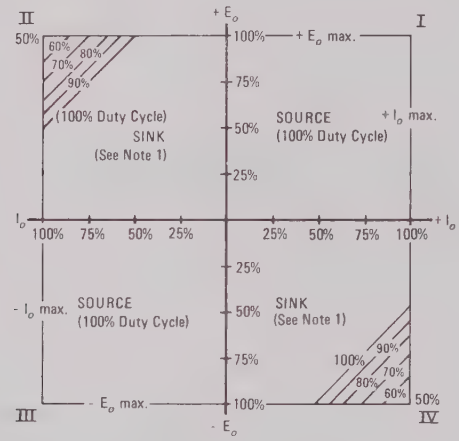


FIG. 1-2 BOP OUTPUT CHARACTERISTIC

NOTE: The values for $\pm E_{o\ max}$ and $\pm I_{o\ max}$ are listed in the model table.

NOTE: The duty cycle of the BOP operating in the SINK mode must be derated as shown on the graph.

Note: The BOP is operating as a SOURCE if the direction of its output voltage is ***the same*** as the direction of its output current. The BOP is operating as a SINK if the direction of its output voltage is ***opposite*** that of its output current. An illustrative case is shown in FIG. 1-3, where the BOP is programmed to deliver a sine wave output and where the load produces a phase shift between the output voltage and current.

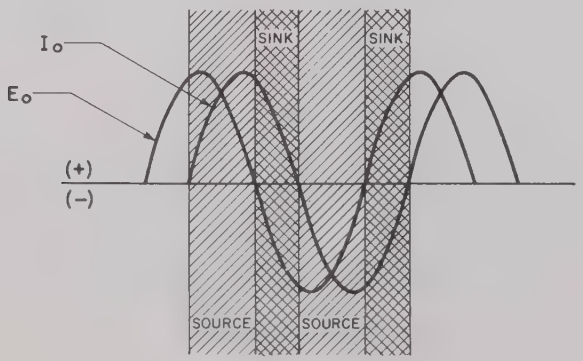
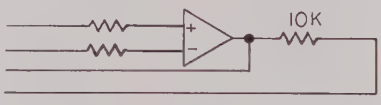
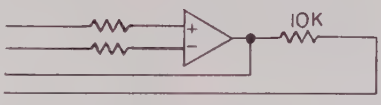


FIG. 1-3 BOP OUTPUT WAVE FORM WITH PHASE SHIFT

B) REAR PROGRAMMING CONNECTORS (See Table 2-2, items 22 and 23)

1) The external rear programming connector, called "PC-12" throughout this manual, is an unwired 50-pin edge connector, providing access to all circuit features. The BOP is delivered with one(1) PC-12 connector, with jumpers wired for local (front-panel) operation. Spare connectors may be purchased from Kepco under the model number "PC-12" for the unwired connector and "PC-15" for a connector wired for local operation. The pin-out for the rear programming connector or (PC-12) is shown below.

PIN	FUNCTION	DESCRIPTION
1	CURRENT LIMIT BIAS	Section III, paragraph 3-31
3	VOLTAGE LIMIT BIAS	Section III, paragraph 3-34
11 9 5 7		Section III, paragraph 3-11 for example
15 13 2 4		Section III, paragraph 3-28 for example
6	$+E_o$ LIMIT INPUT	Section III, paragraph 3-34
8	$+I_o$ LIMIT INPUT	Section III, paragraph 3-31
32	$-E_o$ LIMIT INPUT	Section III, paragraph 3-34
34	$-I_o$ LIMIT INPUT	Section III, paragraph 3-31
10	CURRENT SENSING AMP. OUTPUT	Analog output voltage (0 to ±10V, 1mA max.) proportional to the prevailing BOP output current for remote metering or monitoring.
20	VOLTAGE MONITOR AMP. OUTPUT	Analog output voltage (0 to ±10V, 1 mA max.) proportional to the prevailing BOP output voltage.
12,14	NOT USED	
16,18	CURRENT MODE COMPENSATING TERMINALS	Section I, paragraph 1-10D
26,36	TURN-OFF SIGNAL OUTPUT	Section IV, paragraph 4-25
24	CKT BREAKER CONTROL	Section IV, paragraph 4-25
41	NON-ISOLATED TURN-OFF SIGNAL INPUT	Section IV, paragraph 4-25
47,49	OPTICALLY ISOLATED TURN-OFF SIGNAL INPUT	Section IV, paragraph 4-25
17	VOLTAGE COMPARISON AMP. INPUT	An analog input voltage of 0 to ±10V will produce
19	CURRENT COMPARISON AMP. INPUT	0 to ± full output voltage or current.
22	−10V REFERENCE VOLTAGE, 4mA MAX.	Section III, paragraph 3-11
28	+10V REFERENCE VOLTAGE, 4mA, MAX.	for example
23 25 27 29 31 33	SENSING COMMON	————
30	VOLTAGE MODE COMMAND	Section I, paragraph 1-10L
35	LOCAL/REMOTE OUTPUT FLAG	Section IV, paragraph 4-30
37	+5V	Built in TTL logic supply, 5V @ 40mA max.
38	I_o LIMIT FLAG	Section IV, paragraph 4-30
39	E_o LIMIT FLAG	Section IV, paragraph 4-30
40	E_o MODE FLAG	Section IV, paragraph 4-30
42	I_o MODE FLAG	Section IV, paragraph 4-30

2) AUXILIARY (OPTIONAL) PROGRAMMING CONNECTOR.
For standard BOP models, the space for this connector is covered. If the BOP contains accessory cards for digital programming, the cover is removed and access to the interface card is provided. The method of termination depends on the interface model. Refer to Section III, paragraphs 3-46 through 3-82.

3) Remote turn-off of the BOP by a contact closure, or by an optically isolated input signal.

4) Circuit breaker shut down prevention circuit.

5) REFERENCES: Two reference/bias sources (± 10V at 4 mA MAX.) are provided for control and biasing purposes. These reference sources are available at the rear programming connector (with reference to the "COMMON" terminal). Their specifications are tabulated in Table 1-2.

C) OFFSET NULLING: Controls are provided to zero the initial offsets (E_{io}, I_{io}) of the voltage and current control preamplifiers and the MAIN AMPLIFIERS.

D) LOAD REACTANCE: To realize the full high speed potential of the BOP, the load characteristics should be mainly resistive. Load capacitance and inductance up to 0.2 μF and 0.5 mHy respectively can be tolerated without performance deterioration. The BOP phase-gain versus frequency characteristic is determined by the corner frequency of the response curve ($f_{-3\,dB}$ breakpoint), as indicated in the Dynamic Specification Table (Table 1-3), and the Closed Loop Gain (G_v-Voltage Mode, G_i-Current Mode), as shown in Table 1-1
At unity gain crossover frequency, there is a substancial phase margin which assures stability into resistive loads. Additional phase shift is introduced, however, by reactive loads (RC-in voltage mode, RL-in current mode), which will reduce the phase margin at the unity gain crossover frequency and will cause peaking in the BOP's dynamic response.

If the load's corner frequency is below the BOP's, the system will be stable, but the frequency response will be governed by the load. When operating with inductive loads greater than 0.5 mHenry in the Current Mode, a compensating capacitor may be required across the Current Comparison Amplifier. Two terminals have been provided for this purposes at the Rear Programming Connector (PC-12, pins 16,18).

E) SERIES OR PARALLEL OPERATION: See Section III of this manual.

F) VOLTAGE CONTROL CHANNEL: (Refer to Section III - FIG. 3-1A). The BIPOLAR VOLTAGE AMPLIFIER, with a fixed gain (See Table 1-1 for gain value) is connected, via the MODE switch, to the (unity gain) VOLTAGE PREAMPLIFIER. If the VOLTAGE CONTROL switch is "on", the BOP output voltage can be locally controlled by means of the (front panel) (±) 10 volts bias source, from (−) 100% (through zero) to (+) 100% of the rated value. The VOLTAGE PREAMPLIFIER is provided with a ZERO control and all its terminals are available at the rear programming connector for remote control of the output voltage. Control methods are described in Section III of this manual.

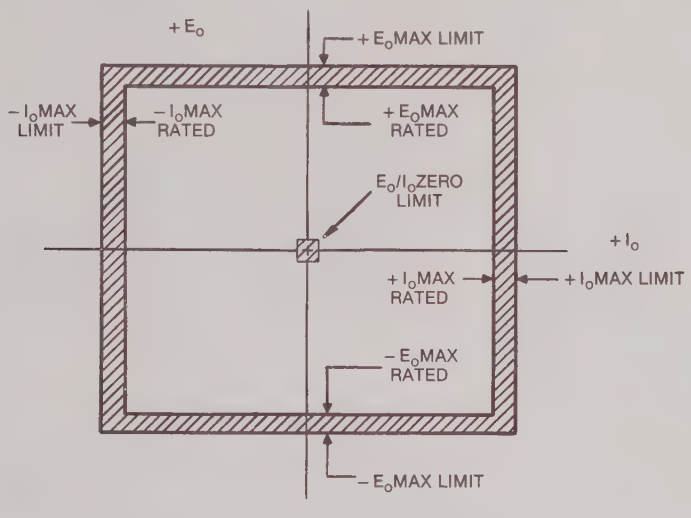
G) MODE SWITCH: The BOP is equipped with a front panel mounted MODE SWITCH, which selects bipolar voltage or bipolar current control. See paragraph 1-10L for remote MODE control.

H) CURRENT CONTROL CHANNEL (Refer to Section III-FIG. 3-1B). The BIPOLAR CURRENT AMPLIFIER, with a fixed gain (see Table 1-1 for gain value), is connected via the MODE switch to the (unity gain) CURRENT PREAMPLIFIER. If the CURRENT CONTROL switch is "on", the BOP output current can be locally (front panel) controlled (by means of the ± 10 volt bias source) from (−)100% (through zero) to (+)100% of the rated value. The CURRENT PREAMPLIFIER is provided with a ZERO control and all its terminals are available at the rear programming connector for remote control of the output current. Control methods are described in Section III of this manual.

J) BOUNDING: (Refer to Section III - FIG. 3-1C & D). The BOP has four output voltage/current limiting circuits (−) E_o LIMIT, (+) E_o LIMIT, (−) I_o LIMIT, (+) I_o LIMIT for overvoltage/overcurrent protection in either operating mode. All limiting circuits can be screwdriver adjusted by means of four front panel controls. In addition, all four limits can be remotely controlled by means of 0 to 10 volt d-c control voltages. The four limits may be programmed independently or the (±) voltage and (±) current limits can be controlled in pairs. The adjustable/programmable limit controls are backed-up by front panel-adjustable limit circuits which define the four boundaries [(±) E_o MAX and (±) I_o MAX.] of the BOP, and provide protection against accidental overprogramming of the adjustable limits.

1-10 J) (Cont'd)

The four boundary quantities (±) E_oMAX. and (±) I_o MAX. as applied to the LIMIT CHANNEL, are actually about 10% greater than the **rated** values E_oMAX. and I_oMAX. for each BOP model. Similarly, the quantities E_o ZERO and I_o ZERO are not really "zero", but approximately 0.2% of the **rated** E_o MAX. and I_o MAX. values for each BOP model. (See graph below).



K) MODE LIGHTS: Four (4) front panel (LED type) indicator lamps monitor the prevailing operating mode of the BOP. For each operating condition (VOLTAGE MODE, CURRENT MODE, ± E_o LIMIT, ± I_o LIMIT) the corresponding indicator lamp energizes. Simultaneous TTL flags available on the REAR PROGRAMMING CONNECTOR. See paragraph 1-10B.

L) REMOTE OPERATING MODE SELECTION. The operating mode of the BOP, normally selected by means of a manual switch on the front panel, may be remotely selected by a remote switch or TTL logic levels. Proceed as follows:

1) Wire the REMOTE/LOCAL FLAG line on the REAR PROGRAMMING CONNECTOR (PC-12, term. 35) to SENSING COMMON. This will cause the front-panel REMOTE LED to light and the front panel MODE switch will be disabled. ALL OTHER FRONT PANEL CONTROLS WILL STILL BE FUNCTIONAL.

2) The operating mode of the BOP may now be controlled by means of terminal 30 on PC-12. With an open teminal (or logic HIGH), the BOP will operate in the Voltage Mode. Returning terminal 30 to SENSING COMMON (or logic LOW) will change the operating mode to Current Mode.

M) STANDARDS: BOP models are designed and tested in accordance with NEMA Standard for Stabilized Power Supplies, d-c output, Publication No. PY-1-1972.

1-11 MECHANICAL SPECIFICATIONS

A) DIMENSIONS: See "Mechanical Outline Drawing". FIG. 1-4.

B) FINISH: See "Mechanical Outline Drawing". FIG.1-4.

C) FRONT PANEL METERS: Two (2) "zero center" meters, monitoring the ± d-c output voltage and the ± d-c output current, are provided; 2½ inches wide, recessed; Accuracy, ±2% full scale.

D) SHIPPING WEIGHT: ¾-RACK BOP MODELS: 51 lbs., 23 Kg, unpacked.
FULL RACK BOP MODELS: 95 lbs., 43 Kg, unpacked.

1-12 ACCESSORIES, SUPPLIED

A) REAR PROGRAMMING CONNECTOR, Kepco Model PC-12, 50-terminal printed circuit connector for all rear programming connections and flag-signal outputs, wired for local (front panel) control of the BOP output. This connector may be ordered wired under Kepco Model PC-15 and unwired as the Model PC-12.

B) (FULL-RACK BOP MODELS ONLY) MOUNTING FLANGES, for installation of the BOP into a standard (19 inch) equipment rack. A PAIR INCLUDED WITH EACH BOP.

C) (FULL-RACK BOP MODELS ONLY) SIDE COVER PLATES, for bench top use, designed to finish the two sides of the instrument when the rack mounting-ears are not installed. A PAIR INCLUDED WITH EACH BOP.

1-13 ACCESSORIES, NOT SUPPLIED

A) REAR PROGRAMMING CONNECTOR, Kepco Model PC-12, unwired.

B) RACK ADAPTER, Kepco Model RA-24; for ¾-rack BOP models and one Kepco ¼-rack model. Filler panel available to cover the empty slot if ¼-rack model is not installed.

C) RACK ADAPTER, Kepco Model RA-37; for ¾-rack BOP models and one Kepco ¼-rack model. Filler panel available to cover empty slot if ¼-rack model is not installed.

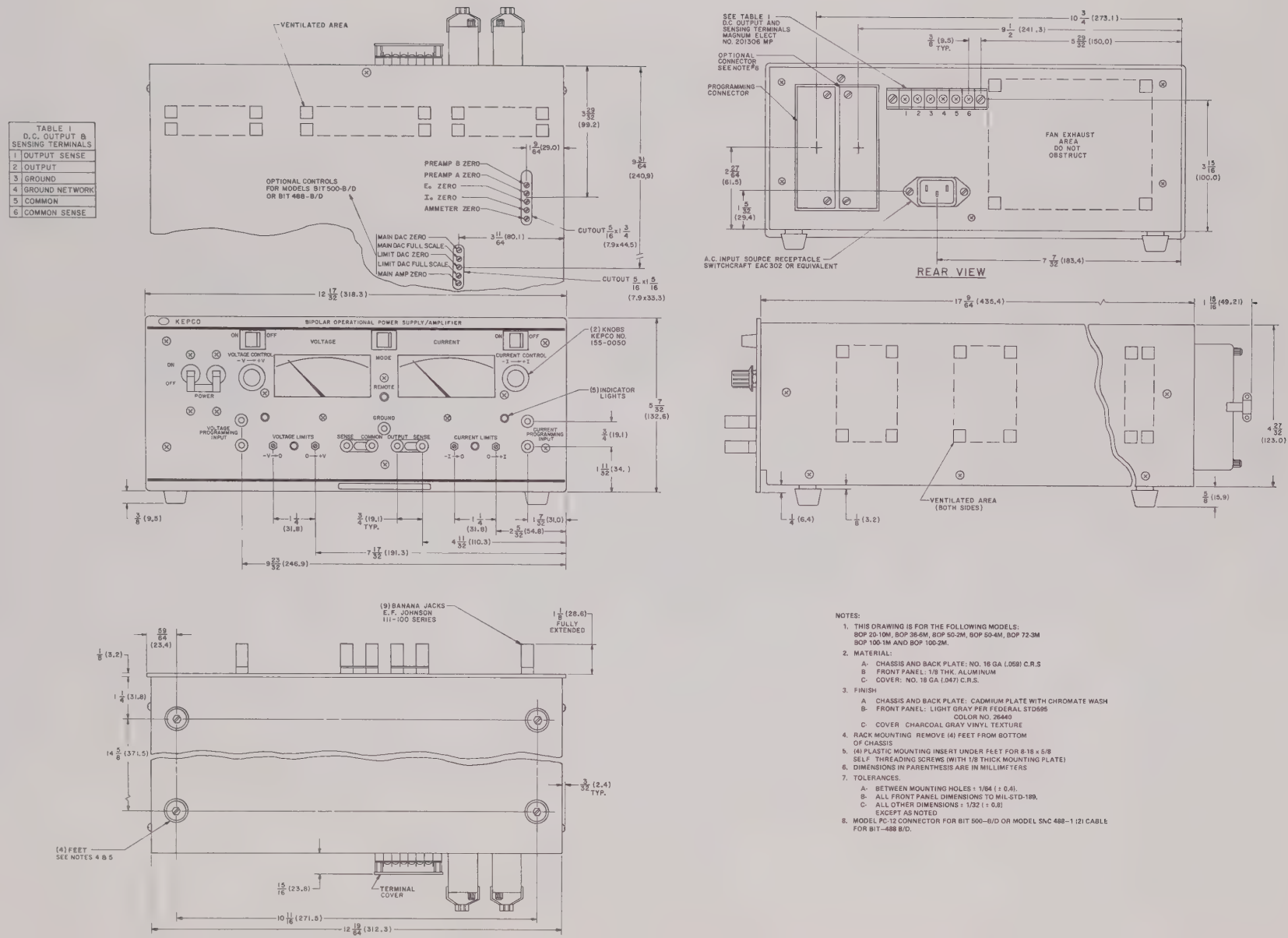


FIG. 1-4 MECHANICAL OUTLINE DRAWING.

NOTES:

1. THIS DRAWING IS FOR THE FOLLOWING MODELS:
   BOP 20-10M, BOP 36-6M, BOP 50-2M, BOP 50-4M, BOP 72-3M
   BOP 100-1M AND BOP 100-2M.
2. MATERIAL:
   - A- CHASSIS AND BACK PLATE: NO. 16 GA (.059) C.R.S
   - B FRONT PANEL: 1/8 THK. ALUMINUM
   - C- COVER: NO. 18 GA (.047) C.R.S.
3. FINISH
   - A CHASSIS AND BACK PLATE: CADMIUM PLATE WITH CHROMATE WASH
   - B- FRONT PANEL: LIGHT GRAY PER FEDERAL STD595 COLOR NO. 26440
   - C- COVER CHARCOAL GRAY VINYL TEXTURE
4. RACK MOUNTING REMOVE (4) FEET FROM BOTTOM OF CHASSIS
5. (4) PLASTIC MOUNTING INSERT UNDER FEET FOR 8-18 x 5/8 SELF THREADING SCREWS (WITH 1/8 THICK MOUNTING PLATE)
6. DIMENSIONS IN PARENTHESIS ARE IN MILLIMETERS
7. TOLERANCES.
   - A- BETWEEN MOUNTING HOLES ± 1/64 (± 0.4).
   - B- ALL FRONT PANEL DIMENSIONS TO MIL-STD-189.
   - C- ALL OTHER DIMENSIONS ± 1/32 (± 0.8) EXCEPT AS NOTED
8. MODEL PC-12 CONNECTOR FOR BIT 500-B/D OR MODEL SNC 488-1 (2) CABLE FOR BIT-488 B/D.

SECTION II—INSTALLATION

2-1 UNPACKING AND INSPECTION

2-2 This instrument has been thoroughly inspected and tested prior to packing and is ready for operation. After careful unpacking, inspect for shipping damage before attempting to operate. Perform the preliminary operational check as outlined in Paragraph 2-8. If any indication of damage is found, file an immediate claim with the responsible transport service.

2-3 TERMINATIONS

A) FRONT PANEL: Refer to FIG. 2-2A and Table 2-2.

B) REAR: Refer to FIG. 2-2B and Table 2-2.

C) INTERNAL CALIBRATION CONTROLS: Refer to FIG. 2-1 and Table 2-1.

REFERENCE DESIGNATION	CONTROL NAME	PURPOSE	ADJUSTMENT PROCEDURE
R31,32	(±)10V CAL.	Reference Voltage Calibration	Sect. V, Par. 5-8A
R41	PREAMP "A" ZERO	Uncommitted Amplifier "A" Zero Adjustment	Sect. III, Par. 3-19
R42	PREAMP "B" ZERO	Uncommitted Amplifier "B" Zero Adjustment.	Sect. III, Par. 3-30
R50	AMMETER ZERO	Sensing Amp. Offset Adjustment	Sect. V, Par. 5-8B
R81	E_o COMP AMP ZERO	Voltage Channel Zero Adjustment	Sect. III, Par. 3-16.
R83	I_o COMP AMP ZERO	Current Channel Zero Adjustment	Sect. III, Par. 3-30
R15A[1]	OPTOCOUPLER LINEARITY	LC301 Optocoupler Linearization	Sect. V, Par. 5-8C

[1] ***Note:*** *R15A for Model BOP 200-1M only*

TABLE 2-1 INTERNAL CALIBRATION CONTROLS.

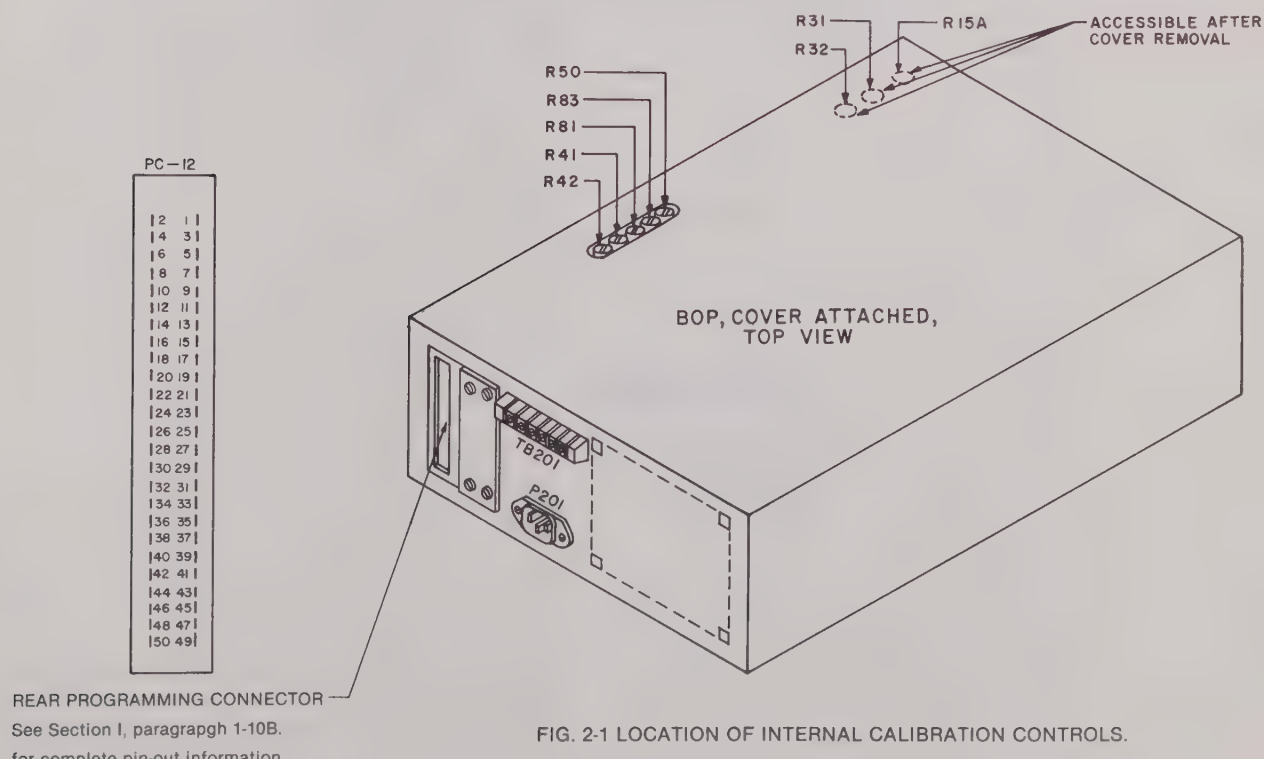
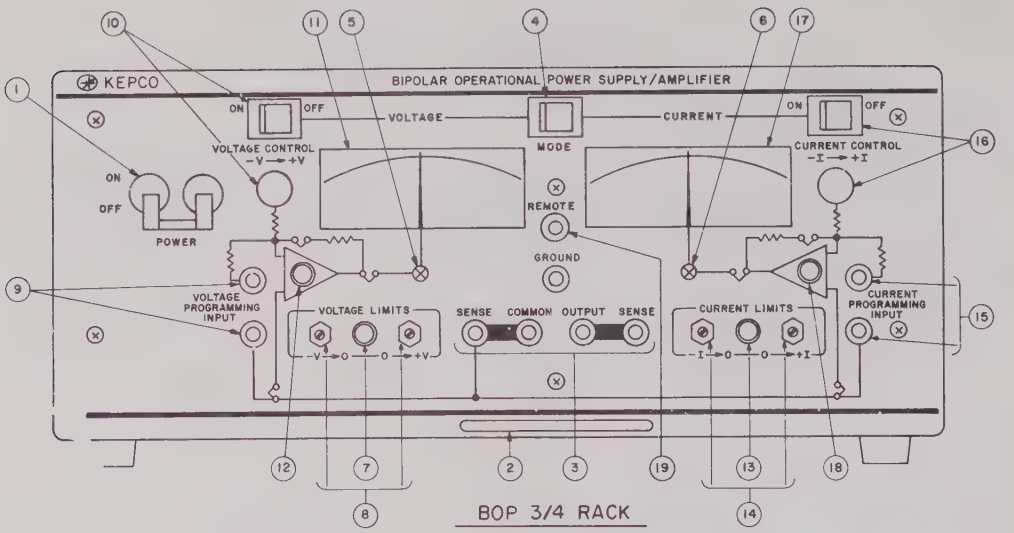
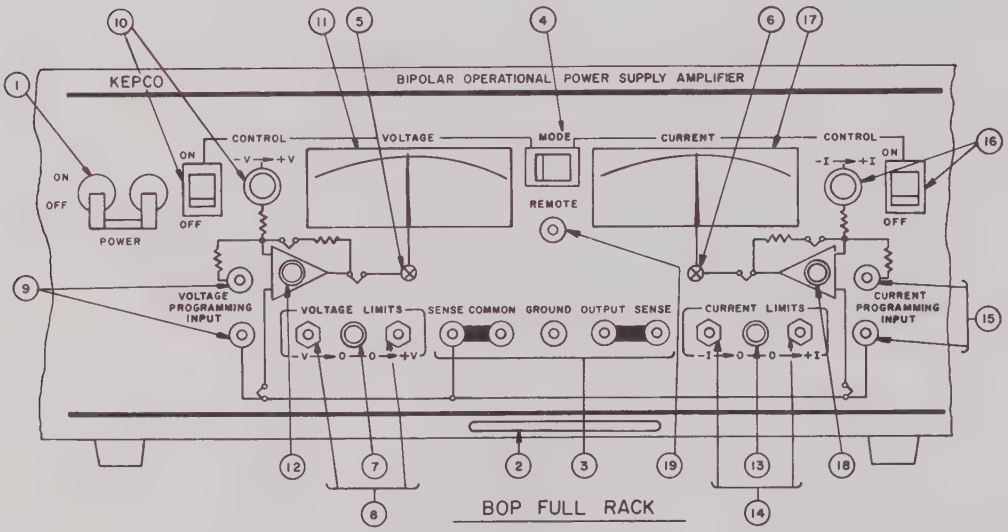
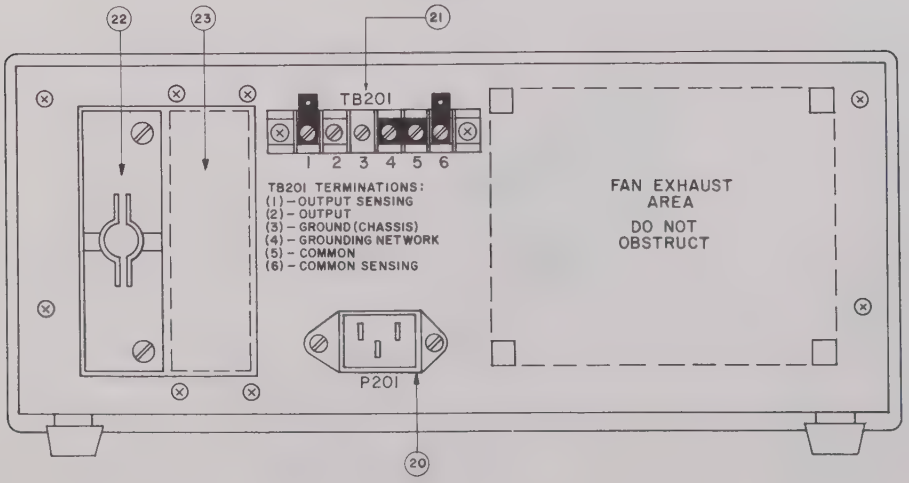


FIG. 2-1 LOCATION OF INTERNAL CALIBRATION CONTROLS.





A) BOP FRONT TERMINATIONS AND CONTROLS



B) BOP REAR TERMINATIONS AND CONTROLS

FIG. 2-2 BOP TERMINATIONS AND CONTROLS

NO. (FRONT)	NAME OF CONTROL OR TERMINATION	FUNCTION
1	A-C POWER	A-C CIRCUIT BREAKER/POWER SWITCH.
2	N.A.	UNIT NAME PLATE
3	± OUTPUT COMMON, GROUND	OUTPUT AND SENSING TERMINALS WITH CHASSIS GROUND (PARALLEL WITH REAR BARRIER STRIP TERMINALS).
4	MODE	OPERATING MODE SELECTOR SWITCH FOR "VOLTAGE" OR "CURRENT" MODE.
5	N.A.	MECHANICAL VOLTMETER ZERO ADJUSTMENT.
6	N.A.	MECHANICAL CURRENT METER ZERO ADJUSTMENT.
7	VOLTAGE LIMIT	LED LAMP, INDICATING VOLTAGE LIMIT OPERATION.
8	± VOLTAGE LIMIT	CONTROLS FOR MANUAL ADJUSTMENT OF THE (±) VOLTAGE LIMITS.
9	INPUT	PROGRAMMING INPUT TERMINALS FOR VOLTAGE CONTROL CHANNEL.
10	VOLTAGE CONTROL	"ON-OFF" SWITCH AND VOLTAGE CONTROL, FOR MANUAL ADJUSTMENT OF THE BOP D-C OUTPUT VOLTAGE (WITH SWITCH "ON").
11	E_o METER	D-C OUTPUT VOLTMETER (READS ALSO AVERAGE A-C SIGNALS).
12	E_o MODE	LED LAMP, INDICATING VOLTAGE MODE OPERATION.
13	CURRENT LIMIT	LED LAMP, INDICATING CURRENT LIMITING OPERATION.
14	± CURRENT LIMIT	CONTROLS FOR MANUAL ADJUSTMENT OF THE (±) CURRENT LIMITS.
15	INPUT	PROGRAMMING INPUT TERMINALS FOR CURRENT CONTROL CHANNEL.
16	CURRENT CONTROL	"ON-OFF" SWITCH AND CURRENT CONTROL, FOR MANUAL ADJUSTMENT OF THE BOP D-C OUTPUT CURRENT (WITH SWITCH "ON").
17	I_o METER	D-C OUTPUT CURRENT METER (READS ALSO AVERAGE A-C SIGNALS).
18	I_o MODE	LED LAMP, INDICATING CURRENT MODE OPERATION.
19	REMOTE/LOCAL	LED LAMP, INDICATING BOP UNDER REMOTE CONTROL WHEN LIT.
NO. (REAR)		
20	P201	A-C POWER INPUT JACK. ACCEPTS 3-WIRE LINE CORD (SUPPLIED).
21	REAR TERMINALS (TB201)	REAR BARRIER STRIP WITH OUTPUT, SENSING AND GROUND TERMINALS.
22	PC-12	REAR PROGRAMMING CONNECTOR.
23	PC-12 FOR BIT-500 CARD OR SNQ CABLE FOR BIT 488 CARD, OR 20-WIRE FLAT CABLE FOR PCA X-3 IF USED WITH TLD 488-16.	AUXILIARY (OPTIONAL) PROGRAMMING CONNECTOR.

TABLE 2-2 BOP TERMINATIONS AND CONTROLS

NOTE: *Numbers correspond to those shown in FIG. 2-2.*

2-4 A-C INPUT REQUIREMENTS

2-5 This power supply is normally supplied for operation on a single phase, nominal 115V a-c line. For operation on other a-c source voltages, refer to FIG. 2-3. Check your prevailing nominal source voltage and change the links on the barrier strip of T201 according to the table provided in FIG. 2-3. The circuit breaker (CB101) remains equally effective at all input voltages.

A-C SOURCE	CONNECT LINKS
104V	(3)—(4), (7)—(8)
115V	(4)—(5), (6)—(7)
208V	(2)—(3), (8)—(9)
230V	(5)—(6)

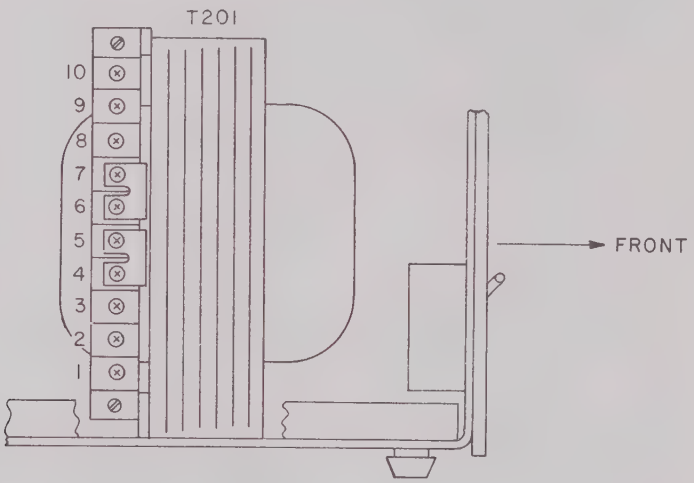


FIG. 2-3 A-C SOURCE VOLTAGE SELECTION.

2-6 COOLING

2-7 The components in the BOP power supply rely on forced air cooling for the maintenance of their operating temperature. SIDE PANEL OPENINGS AND THE TOP OF THE CASE MUST BE KEPT CLEAR FROM ALL OBSTRUCTIONS TO ENSURE AIR CIRCULATION. Periodic cleaning of the interior of the power supply is recommended. **If the BOP is rack-mounted or installed into confined spaces, care must be taken that the ambient temperature (the temperature immediately surrounding the power supply) does not rise above 55°C (≈157°F).**

2-8 PRELIMINARY CHECKOUT

NOTE: *THE REAR PROGRAMMING CONNECTOR (PC-12) MUST BE ATTACHED TO THE BOP AND MUST BE WIRED AS SHOWN ON THE MAIN SCHEMATIC DIAGRAM, SECTION VI.*

2-9 A simple operating check after unpacking and before permanent installation, is advisable to ascertain whether the BOP has suffered damage in shipment. *Refer to FIG. 2-2 and Table 2-2 FOR THE LOCATION AND DESIGNATION OF THE OPERATING CONTROLS AND TERMINALS. Proceed as follows:*

A) Connect the BOP to a 115V a-c source, or refer to paragraph 2-4 for conversion to other a-c input voltages if required.

B) ***Note:*** *The rear sensing links must be attached to the rear barrier strip (TB201) of the BOP as shown in FIG. 2-2 and the rear connector (PC-12) must be attached, wired for LOCAL CONTROL, and secured.*

C) Set the BOP front panel controls as follows (refer to FIG. 2-2). The controls will be identified here and in the following manual text with the nomenclature used in Table 2-2 and identifying numbers used in FIG. 2-2):

1) MODE switch (4), set to VOLTAGE.

2) VOLTAGE CONTROL (10), set SWITCH to "ON", VOLTAGE CONTROL to its extreme counterclockwise position.

3) A-C CIRCUIT BREAKER/POWER SWITCH (1) to "ON".

D) The "E_o MODE" Lamp (12) will be "on".

E) Turn the VOLTAGE CONTROL (10) clockwise through its range, while observing the front panel VOLTMETER (11). The BOP output voltage should smoothly respond, from the maximum negative output voltage, over zero, to the maximum positive output voltage of the BOP. Turn A-C CIRCUIT BREAKER/POWER SWITCH (1) "off".

F) Connect a short circuit between the (±) OUTPUT and the COMMON front panel output terminal (3). Set the BOP front panel controls as follows:

1) MODE SWITCH (4), set to "CURRENT".

2) CURRENT CONTROL (16), set SWITCH to "ON", CURRENT CONTROL to its maximum counterclockwise position.

3) A-C CIRCUIT BREAKER/POWER SWITCH (1) to "ON".

G) The "I_o MODE" Lamp (18) will be "on".

H) Turn the CURRENT CONTROL (16) clockwise through its range, while observing the front panel AMMETER (17). The BOP output current should smoothly respond, from the maximum negative output current, over zero, to the maximum positive ouput current of the BOP. Turn A-C CIRCUIT BREAKER/POWER SWITCH (1) "off". Remove the short circuit from the output terminals. THIS CONCLUDES THE PRELIMINARY CHECK-OUT OF THE BOP.

2-10 INSTALLATION FOR ¾ RACK BOP MODELS

2-11 These BOP models may be bench operated or installed in the RA-24 or RA-37 Rack Adaptors, as listed in Section I, Paragraph 1-13. Installation instructions are provided with the respective rack-adaptor models. For rack-mounting, or mounting onto **any** flat surface,the (4) bottom aluminum feet of the BOP must be removed. Four (4) plastic mounting inserts are provided on the bottom of the BOP chassis. See Section I, FIG. 1-4, "Mechanical Outline Drawing".

NOTE: *FOR ALL INSTALLATIONS INTO CONFINED SPACES, CARE MUST BE TAKEN THAT THE TEMPERATURE IMMEDIATELY SURROUNDING THE UNIT DOES NOT EXCEED THE MAXIMUM SPECIFIED AMBIENT TEMPERATURE (55°C).*

2-12 INSTALLATION OF FULL-RACK BOP MODELS (Refer to Section I, Fig. 1-4 and to FIG. 2-4).

2-13 Full-rack BOP models are delivered with the FIXED ANGLE BRACKETS and the CHASSIS SIDE SUPPORT BARS installed. For bench operation, both of these components may be removed. The full-rack BOP unit may be installed into standard (19 inch) equipment racks, or onto any other flat surface. For installation, the four (4) bottom aluminum feet must be removed. If chassis slides are not used, the BOP may be installed onto any flat surface by means of the provided plastic mounting inserts on the bottom of the BOP chassis.

2-14 SLIDE INSTALLATION. The CHASSIS SLIDE SUPPORT BARS of the BOP are pre-drilled to accept JONATHAN SERIES 110 QD slides. The following slide models can be accomodated:

MODEL	MOUNTING HOLES USED				
	A	B	C	D	E
110 QD-20-2	X	X	0	X	DR
110 QD-22-2	X	0	X	0	X
110 QD-24-2	X	0	X	0	DR

KEY: X = HOLE USED, **0** = HOLE NOT USED, **DR** HOLE MUST BE DRILLED INTO CHASSIS PART OF SLIDE, EACH SIDE 0.199 DIA., 16¼" FROM "A" HOLE.

2-15 PROCEDURE (Refer to FIG. 2-4):

1) REMOVE SCREWS "A" through "E" from left and right CHASSIS SLIDE SUPPORT BARS. (Do not discard).
2) Determine the required hole-pattern for the selected slide model from the table.
3) Drill the "E" hole into both, left and right chassis section of slide if required.
4) Mount the chassis section of the slide to the left and right side of the BOP, as shown in FIG. 2-4. Use the same 10-32 x ½" Mounting Screws which you removed in step (1).

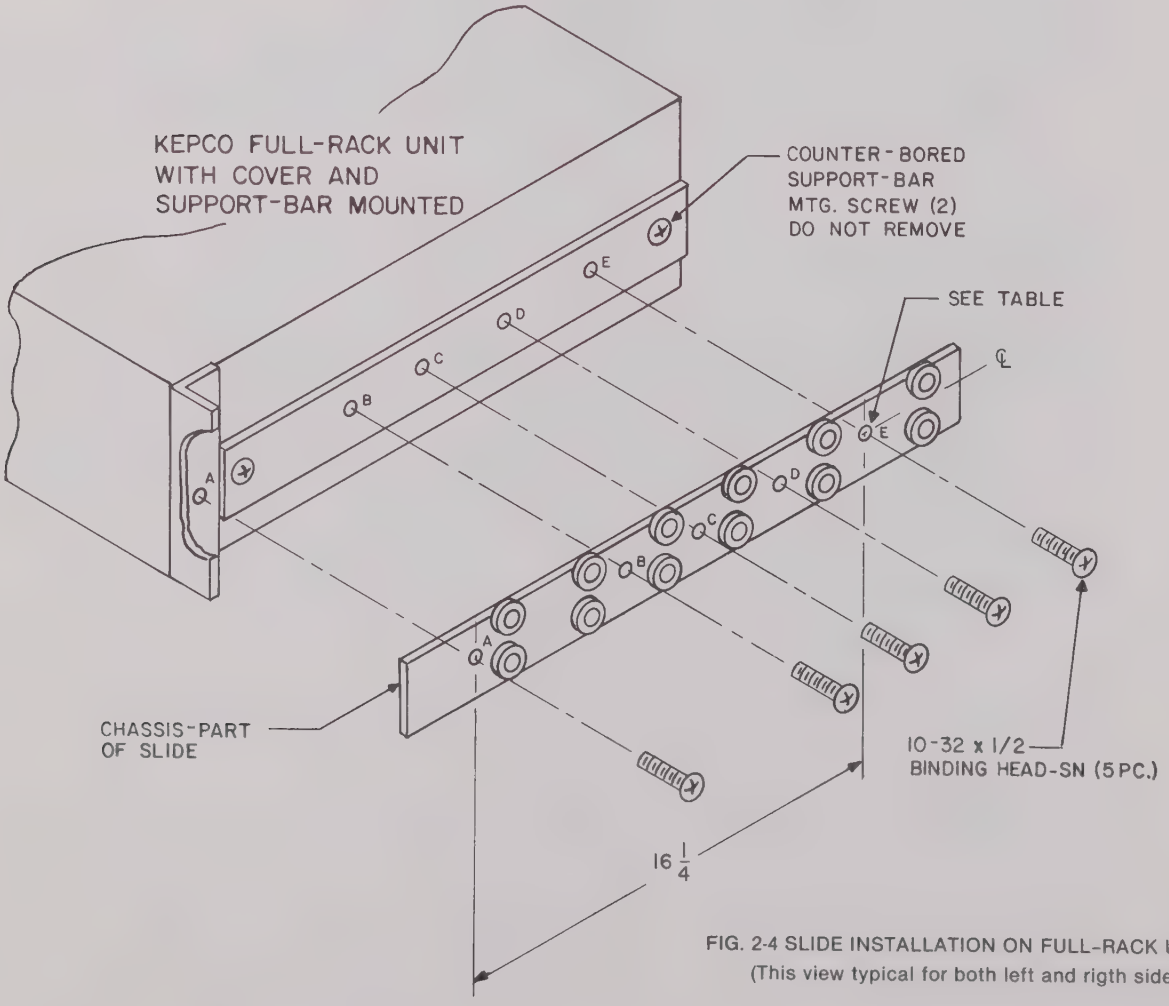


FIG. 2-4 SLIDE INSTALLATION ON FULL-RACK UNITS
(This view typical for both left and rigth side)

NOTE: *If slide installation (as described above) is not desired, other means of supporting the unit in the rear must be provided (additional rear brackets or a solid platform, for example) since the front angle brackets alone are not sufficient to support the full weight of the unit.*

SECTION III—OPERATION

3-1 INTRODUCTION

3-2 BOP BIPOLAR OPERATIONAL POWER SUPPLIES can be used in a great variety of applications. As a PRECISION VOLTAGE or CURRENT SOURCE, the BOP output can be controlled locally by means of the front panel bipolar VOLTAGE and CURRENT controls or remotely by means of resistance or by voltage signals. Independently adjustable or remotely programmable limit circuits for both output voltage and output current protect a sensitive load from any overvoltage or overcurrent. As a BIPOLAR AMPLIFIER, the BOP output responds for example to such input signals as sine, square or triangular waves. A (±) 10 volt input signal will program the BOP output (voltage or current) through its rated output ranges. Built-in preamplifiers, for the voltage, as well as the current channel of the BOP, permit amplification of the control signals to the required amplitude and provide the interface with high as well as low impedance signal sources.

3-3 Detailed examples of the more popular applications are described in the following paragraphs. Before actual operation, however, the following general comments on the operation of the BOP should be carefully considered:

SAFETY PRECAUTIONS

1) Exercise care in making all connections to and from the BOP terminals. REMOVE A-C POWER FROM THE BOP BEFORE MAKING ANY CONNECTIONS.
2) Wires and/or cables, connected from the BOP terminals to external components or programming devices must be properly insulated and securely terminated on both sides to make accidental touch impossible. DO NOT USE BANANA PLUGS WITH EXPOSED SCREWS OR OTHER EXPOSED METAL PARTS AT THE FRONT PANEL OUTPUT TERMINALS!
3) The BOP chassis and cover must be safety-grounded to a reliable a-c source ground. A safety-ground may be established by using a grounded a-c power outlet or, if the latter is not available, by means of a separate wire, from the provided "ground" terminal to a reliable a-c source ground point.
4) THE COMMON OUTPUT TERMINAL OF THE BOP SHOULD BE SIGNAL GROUNDED. If for any reason, grounding of the output is not possible, additional precautions must be taken to make any access to the isolated output impossible.

A) DIAGRAMS. Application and test set up diagrams on the following pages show the symbolic and simplified representation of the BOP circuitry in four (4) separate diagrams, as indicated in FIG. 3-1. The diagrams represent the four programmable circuits of the BOP.

FIG. 3-1A: Voltage Control Channel.

FIG. 3-1B: Current Control Channel.

FIG. 3-1C: (±)E_o Limit Circuits.

FIG. 3-1D: (±)I_o Limit Circuits.

The ***complete*** simplified diagram is represented in the fold-out page at the end of Section IV. THE FOUR CIRCUITS CAN BE PROGRAMMED SEPARATELY AS DESCRIBED IN THE EXAMPLES IN THIS SECTION, OR THEY CAN BE USED SIMULTANEOUSLY AS THE APPLICATION REQUIRES, WITH THE EXCEPTION OF THE TWO (2) MAIN BIPOLAR VOLTAGE AND CURRENT CHANNELS WHICH ARE MANUALLY SELECTED BY THE FRONT PANEL MODE SWITCH OR REMOTELY BY TTL SIGNALS AND CANNOT BE OPERATED SIMULTANEOUSLY.

The numbered terminals in the diagrams correspond to the connector terminals on the REAR PROGRAMMING CONNECTOR. **The terminal designated C corresponds to pin numbers 23,25,27,29,31 or 33 on PC-12.**

NOTE: *BOP's have front and rear output terminals. Only the front terminals are shown on all subsequent simplified diagrams.*

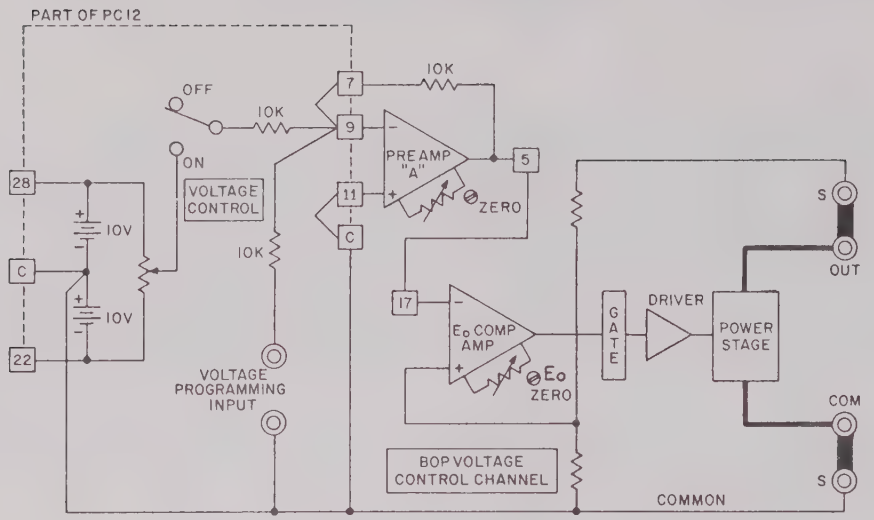


FIG. 3-1A BOP VOLTAGE CONTROL CHANNEL

NOTE: *Mode Switch position: "VOLTAGE".*

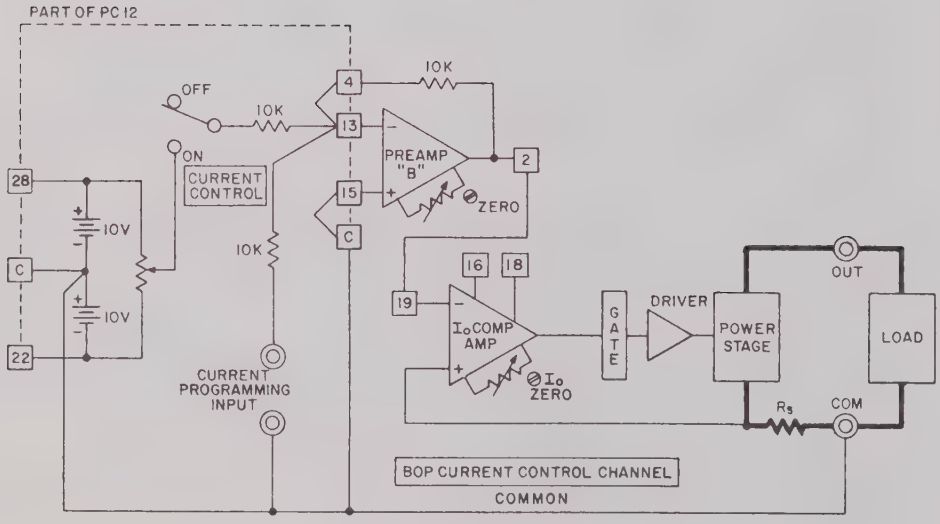


FIG. 3-1B BOP CURRENT CONTROL CHANNEL

NOTES: *1) Mode Switch position: "CURRENT".*

2) For inductive loads in excess of 0.5 mHy, the BOP output response may be optimized by placing a capacitor across terminals 16 and 18 of the I_o COMP. AMP.

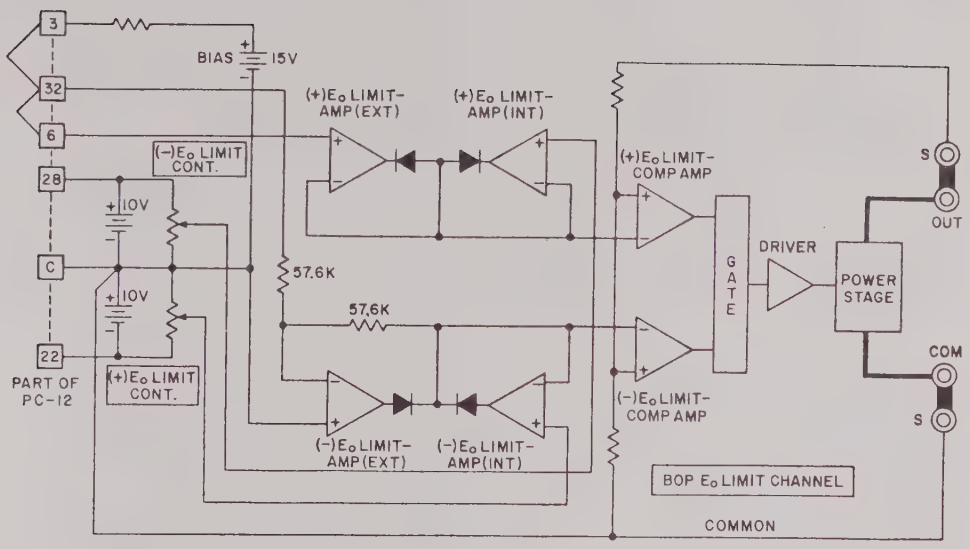


FIG. 3-1C BOP (±) VOLTAGE LIMITING CIRCUIT

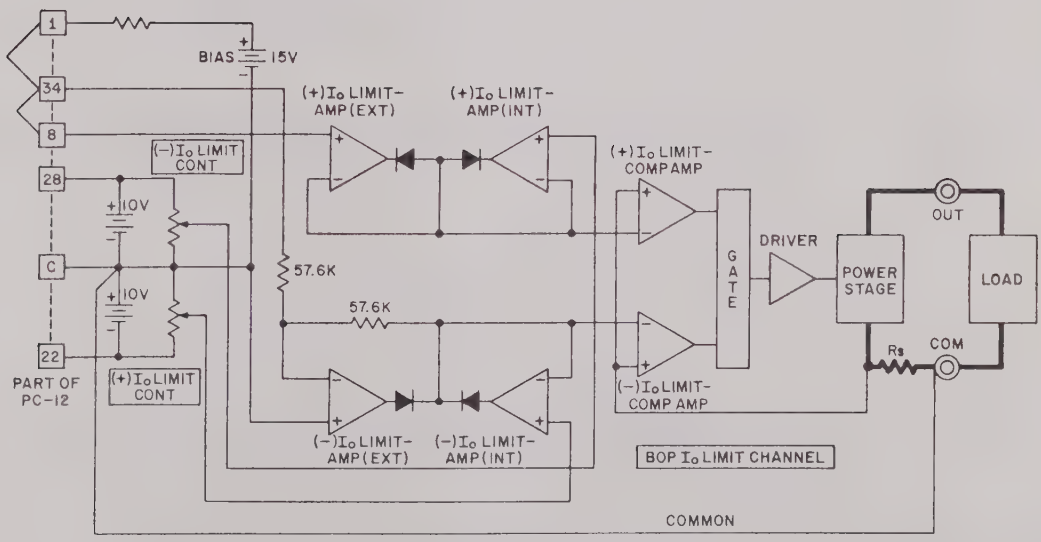


FIG. 3-1D BOP (±) CURRENT LIMITING CIRCUIT

B) LOAD CONNECTION (I). The basic interconnections between the BOP and the load are shown in FIG.'s 3-2A and 3-2B. The load wire size for the 2-wire connection shown should be as large as practicable to keep the series resistance and inductance low. In addition, the load wire pair should be tightly twisted, to reduce possible "pick-up" from stray magnetic fields. The basic 2-wire connection is useful where the voltage drop in the load wires is of minor consequence, as for example, operation into a constant load or in a constant current operating mode.

C) LOAD CONNECTION (II). The recommended load connection for all applications requiring minimum load effect across a remote load is shown in FIG. 3-3A and 3-3B. A twisted, shielded pair of wires (No. 20 AWG minimum) are connected from the BOP sensing terminals to the load. This "remote error sensing" technique will compensate for load wire voltage drops up to 0.5 volts per wire.
NOTE: *OBSERVE POLARITIES: THE COMMON SENSING WIRE MUST GO TO THE "COMMON" LOAD WIRE, THE (±) OUT SENSING WIRE MUST GO TO THE "(±) OUT" LOAD WIRE.*

D) A-C GROUND. (Refer to FIG.'s 3-2, 3-3). The metal cases of electronic equipment which is operated from the a-c power line must be kept at ground potential at all times. If the 3-wire line cord with 3-prong safety plug (supplied with this equipment) is used in combination with a properly grounded a-c power outlet, this is taken care of automatically. If an adapter for a non-grounded outlet is used, however, the case must be grounded separately. A separate "GROUND" terminal is provided for this purpose on the front panel as well as on the rear of the BOP. (See Section II, FIG. 2-2).

E) D-C (SIGNAL) GROUND. (Refer to FIG.'s 3-2, 3-3). Specified ripple and noise figures for operational power supplies are valid only with the COMMON side of the output/load circuit returned to a common ground point (refer to Section I, Table 1-2). The COMMON terminal of the BOP output is shown grounded in FIG.'s 3-2A through 3-3B, since it is "common" to both, internal reference source and any external signal source. If the application requires, the COMMON of the BOP may be floated up to 500V d-c off ground. In this case, however, the common mode current (specified in Section I, Paragraph 1-8E, will flow through the impedance of whatever circuit is placed between COMMON and ground and will give rise to a common mode voltage. The signal ground point in the BOP/load circuit must consist of a single point only, to which all input source grounds, shields and load grounds are connected. Multiple signal grounds in the BOP output/load circuit may cause "ground-loop" problems, since noise signals develop across the impedances between the multiple ground points. The exact physical location of the "best" single ground point must be carefully selected for minimum ripple/noise output.

F) EXTERNAL PROGRAMMING RESISTORS. External programming resistors should be high-quality units, with low-temperature coefficients. Resistors should be selected carefully, since in most applications, the limitations for stability and drift are due, not to the BOP, but to the programming resistors. Selection criteria for resistors are:

1) TEMPERATURE COEFFICIENT
2) LEAKAGE (IN VALUES ABOVE 100K OHM)
3) HUMIDITY EFFECTS
4) DRIFT WITH TIME
5) SELF-HEATING (POWER DISSIPATION)
6) TOLERANCE.

G) For variable resistors (potentiometers or rheostats) similar selection criteria apply. In addition, such specifications as listed below should be carefully considered if the application requires:

1) END RESISTANCE
2) LINEARITY
3) CAPACITIVE AND INDUCTIVE EFFECTS

H) ACTIVE PROGRAMMING SOURCES. External programming sources (Signal Generators, etc.,) or reference sources should have temperature coefficients and drift specifications comparable to (or better than) the BOP Power Supply. CAUTION: A-C source-operated programming sources must have their output isolated from the case.

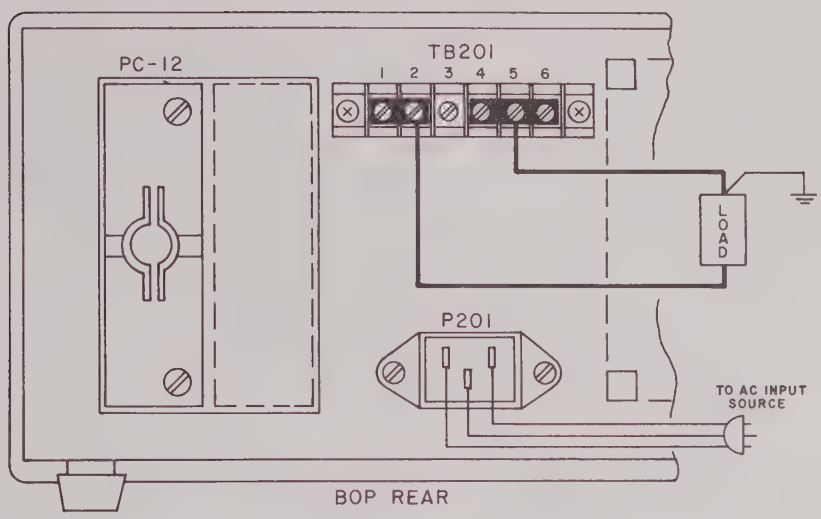


FIG. 3-2A LOAD CONNECTION AT THE REAR, WITHOUT ERROR SENSING.

NOTE: FRONT SENSING LINKS MUST BE REMOVED. REAR SENSING LINKS MUST BE CONNECTED AS SHOWN.

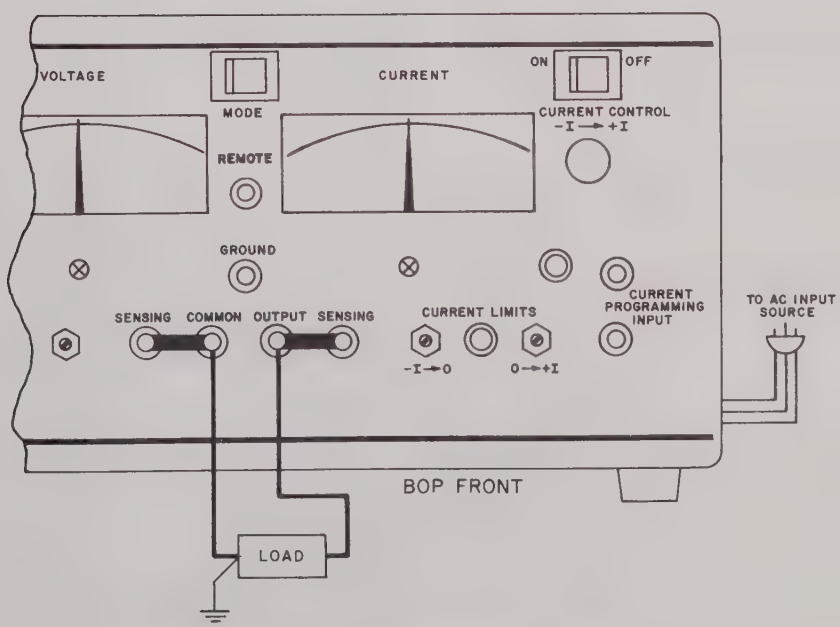


FIG. 3-2B LOAD CONNECTION AT THE FRONT, WITHOUT ERROR SENSING.

NOTE: REAR SENSING LINKS MUST BE REMOVED. FRONT SENSING LINKS MUST BE CONNECTED AS SHOWN.

NOTE 1) FRONT AND REAR SENSING LINKS MUST BE REMOVED.

NOTE 2) FOR APPLICATIONS REQUIRING VERY LONG CONNECTIONS TO THE LOAD, ADDITIONAL EXTERNAL CAPACITORS (C_x IN FIG.'S 3-3A AND 3-3B) SHOULD BE CONNECTED AS SHOWN, TO COMPENSATE FOR THE LEAD INDUCTANCE OF THE CONNECTING WIRES.

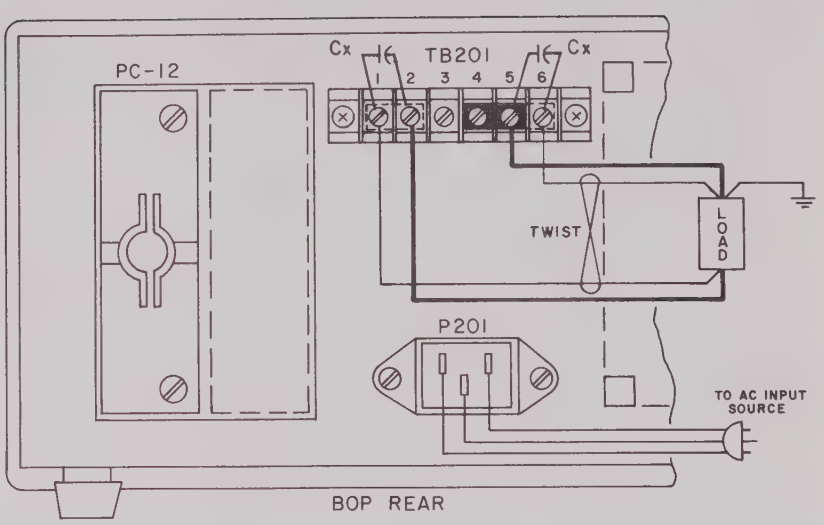
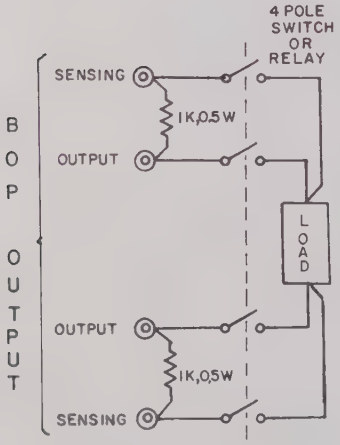


FIG. 3-3A LOAD CONNECTION AT THE REAR, WITH ERROR SENSING.

NOTE 3) FOR APPLICATIONS REQUIRING MANUALLY SWITCHED OR RELAY DRIVEN OUPUT CONNECTIONS, EXTERNAL RESISTORS MUST BE CONNECTED AS SHOWN. ALL CONNECTIONS SHOULD BE MADE AND BROKEN SIMULTANEOUSLY.



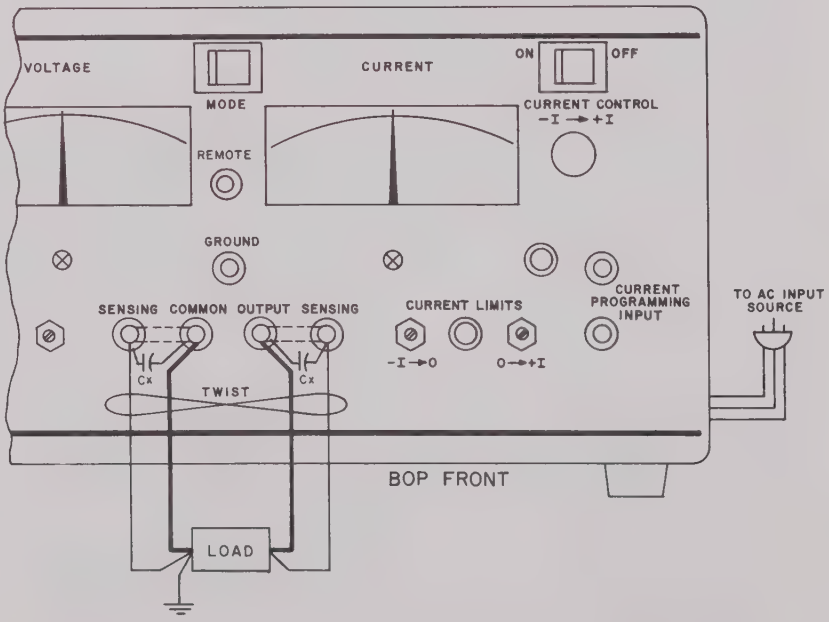


FIG. 3-3B LOAD CONNECTION AT THE FRONT, WITH ERROR SENSING.

J) EXTERNAL LEADS. Shielded (preferably twisted) lead pairs are recommended for all input connections to the BOP control channels. The shield should be connected (single-ended) to the chosen signal ground point. Shielded leads should be held as short as practicable. Output leads must be voltage rated at least for the maximum BOP output voltage.

3-4 BEFORE USING THE BOP IN ANY APPLICATION...PLEASE REFER TO SECTION II TO GET ACQUAINTED WITH THE OPERATING CONTROLS AND THE A-C POWER REQUIREMENTS. REFER TO THIS SECTION (SECTION III) FOR INFORMATION ON LOAD CONNECTIONS AND GROUNDING.

3-5 BOP OPERATION WITH LOCAL (FRONT PANEL) OUTPUT CONTROL

3-6 VOLTAGE MODE OPERATION WITH CURRENT LIMITING. The BOP may be used as a stabilized (d-c) source of positive or negative voltage with output current limiting (for either polarity) pre-selected for the application at hand.

3-7 PROCEDURE (Refer to Paragraph 3-4)

1) Determine the output voltage and current requirements of your load. Set the BOP MODE switch to the VOLTAGE position and the VOLTAGE CONTROL SWITCH to "ON".

2) With the BOP A-C CIRCUIT BREAKER/POWER SWITCH "off", connect a short circuit across the output terminals. Turn the BOP "on" again.

3) Adjust the I_o LIMIT CONTROLS for both polarities as required, monitoring the OUTPUT CURRENT METER for the correct limiting value. Proceed as follows: Turn VOLTAGE CONTROL fully counterclockwise. Adjust the "(–) I_o LIMIT CONTROL". Turn the VOLTAGE CONTROL to the center of its range. Turn the A-C POWER switch "off" and remove the short circuit from the output and reconnect the load.

4) Turn the BOP "on" again, and adjust the operating voltage by means of the VOLTAGE CONTROL to the value required.

NOTE: *If the output current exceeds the pre-adjusted value at any time the VOLTAGE MODE LIGHT will go out and the (±) I_o LIMIT LIGHT will go on. After the cause of the overcurrent is eliminated, the indicator lights will return to their initial status.*

3-8 CURRENT MODE OPERATION WITH VOLTAGE LIMITING. The BOP may be used as a stabilized d-c source of positive or negative current, with output voltage limiting (for either polarity), pre-selected for the application at hand.

3-9 PROCEDURE (please refer to Paragraph 3-4)

1) Determine the output current and voltage requirement of your load. Perform I_o LIMIT adjustment as described in Paragraph 3-7, steps 2 and 3. Set the BOP MODE SWITCH to the CURRENT position and the CURRENT CONTROL switch to "ON".

2) Turn the A-C CIRCUIT BREAKER/POWER SWITCH "on", and adjust the (±) E_o LIMIT CONTROLS to the required output (compliance) voltage. Turn the A-C CIRCUIT BREAKER/POWER SWITCH "off".

3) Connect the load and turn A-C CIRCUIT BREAKER/POWER SWITCH "on". Adjust the required operating current by means of the CURRENT CONTROL as required.

3-10 BOP OPERATION WITH REMOTE CONTROL OF THE VOLTAGE CONTROL CHANNEL.

3-11 REMOTE D-C OUTPUT VOLTAGE CONTROL BY RESISTANCE. As seen in FIG. 3-4, and as described in a previous paragraph (Paragraph 3-6) the BOP d-c output potential can be controlled within its specified range by means of the VOLTAGE CONTROL, with the VOLTAGE CONTROL SWITCH in the ON position. PREAMP "A" with the built-in feedback and input resistors, has a gain of one and the fixed gain of all BOP models is designed so that a d-c input signal of zero to (±)10 volt will control the BOP output through its specified range. In the local (front panel) control mode, the d-c control potential is applied via the VOLTAGE CONTROL. In the remote control mode, a similar control circuit, located external to the BOP is substituted for the internal control elements.

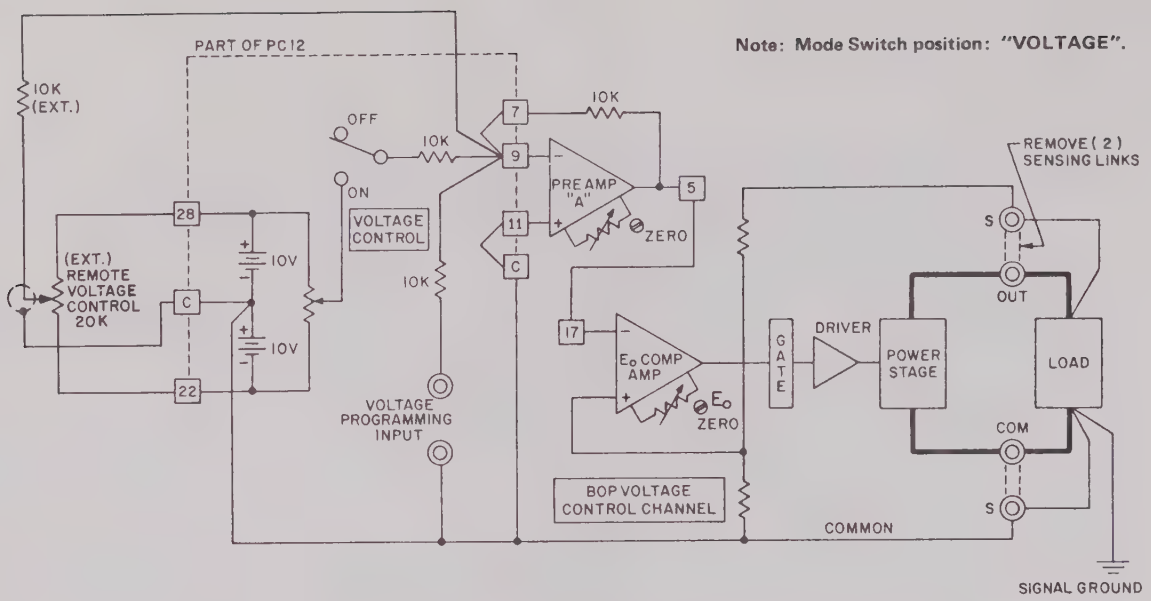


FIG. 3-4 REMOTE POTENTIOMETER CONTROL OF THE BOP D-C OUTPUT VOLTAGE

3-12 As shown in FIG. 3-4, this control method can readily be performed remotely, by setting the VOLTAGE CONTROL SWITCH to the OFF position and connecting an external REMOTE VOLTAGE CONTROL as indicated in FIG. 3-4.

3-13 Two-terminal resistance control of the d-c voltage (for example, by means of a Decade Box) can be exercised as shown in FIG. 3-5.

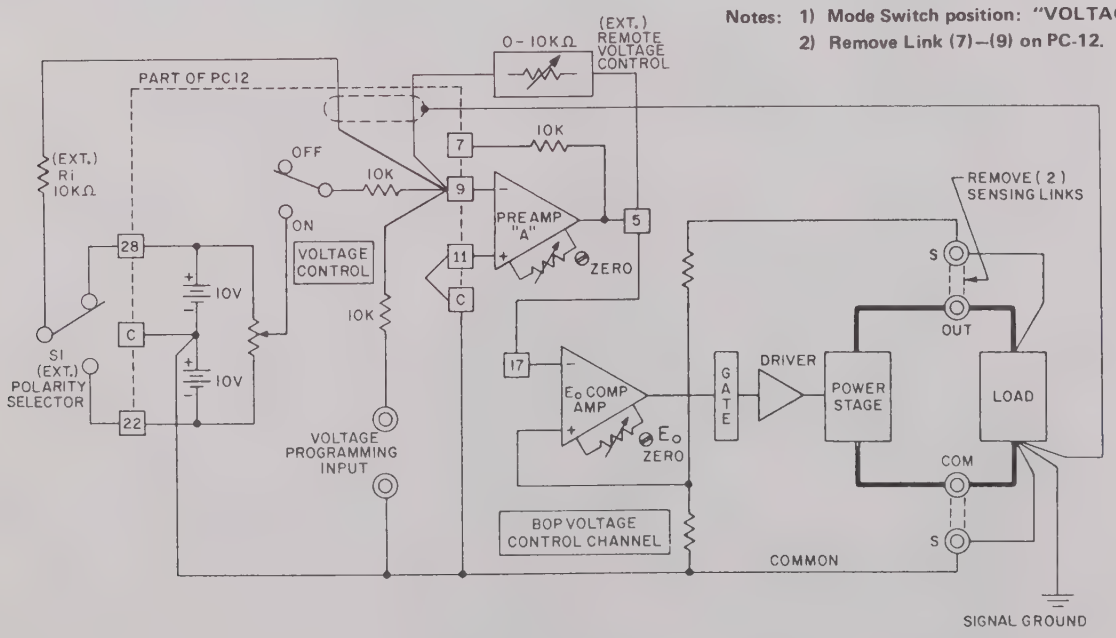


FIG. 3-5 REMOTE D-C OUTPUT VOLTAGE CONTROL BY MEANS OF A TWO-TERMINAL RESISTANCE (DECADE).

3-14 The external switch (S1), connected across the (±) reference voltage is used to pre-select either positive or negative output, by setting it to the applicable reference voltage polarity.

3-15 PREAMP "A" functions here as an inverter. Its output can be expressed by the equation:

$$E_{o\ (PREAMP\ "A")} = -E_{ref}\ (R_f/R_i).$$

R_f = Decade Resistor.
R_i = Ext. Input Resistor

Since E_{ref} = (±)10 volts and the gain ratio R_f/R_i is variable from zero to one, its output ($E_{o\ PREAMP\ "A"}$) will vary linearly from zero to (±)10 volts with the change in the decade resistance (R_f). As a consequence, the BOP output voltage will also vary linearly with the change in decade resistance.

3-16 This programming system can be calibrated very accurately by setting the REMOTE VOLTAGE CONTROL (Decade) to zero and adjusting zero output volts at the BOP E_o ZERO control, monitoring at the BOP output with a digital voltmeter. The maximum output voltage is calibrated by making all or part of R_i a rheostat and adjusting it, with the REMOTE VOLTAGE CONTROL at maximum resistance, to the maximum BOP output voltage.

3-17 **REMOTE OUTPUT VOLTAGE CONTROL BY MEANS OF D-C SIGNAL VOLTAGE.** The BOP d-c output voltage can be controlled directly by a (±)10V d-c signal, applied to the front panel VOLTAGE PROGRAMMING INPUT terminals. An interesting example of this application is the BOP output voltage control with a Kepco SN Digital Programmer for example. The digital input to the SN programmer can be provided by a computer, or manually by means of a keyboard. The analog output from the SN is from zero to ± 10 volts and constitutes the input program for the BOP.

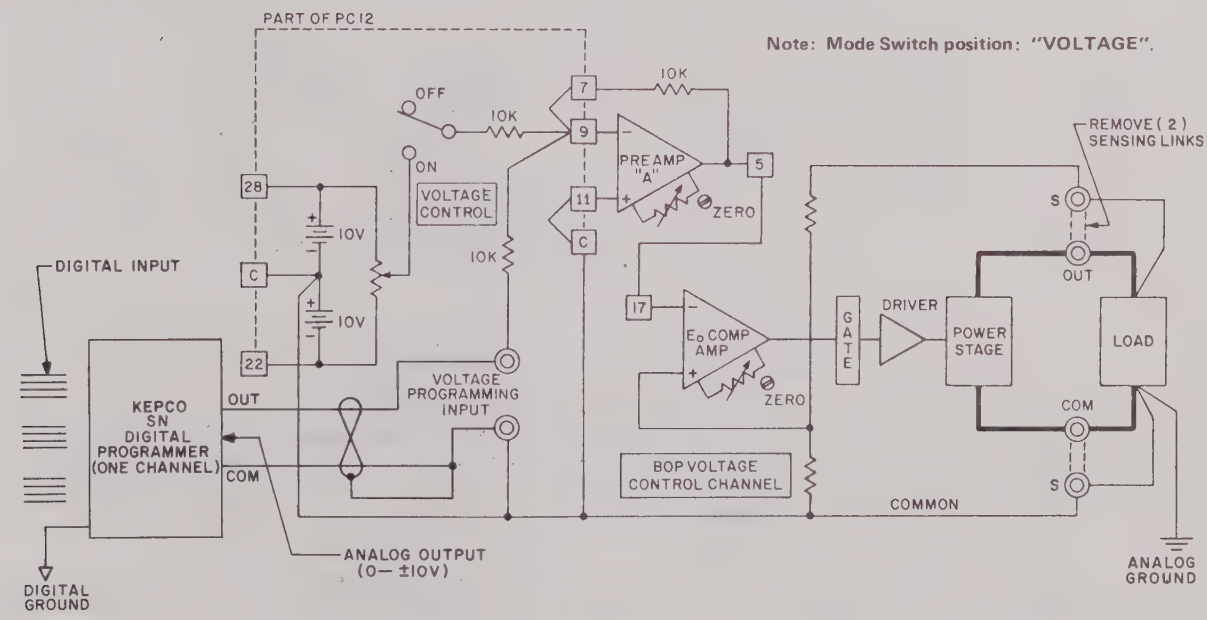


FIG. 3-6 DIGITAL CONTROL OF THE BOP D-C OUTPUT VOLTAGE.

3-18 The connections between the SN Programmer and the BOP are illustrated in FIG. 3-6. This programming system provides a resolution of 12-bits with a linearity of (±)½ LSB (0.0122%). The digital and the power supply grounds are isolated (optical isolation) to 1000 volts. Calibration of the system is performed with the provided controls on the SN Programmer. See paragraphs 3-46 through 3-82 for a description of available Kepco Digital Programming devices suitable for use with the BOP.

3-19 Since all terminals of PREAMP "A" are available at the REAR PROGRAMMING CONNECTOR, d-c output voltage control can be exercised in many other ways. PREAMP "A" can be treated as an uncommitted operational amplifier, with its applicable transfer-functions. Its ***initial*** offsets can be zeroed with the provided control, while the offset ***variations*** are specified in Section I of this manual (refer to Table 1-2). The basic principle of d-c output voltage control of the BOP is that a control voltage of (±)10 volts at 1 mA at the VOLTAGE PROGRAMMING INPUT (with the built-in feedback/input resistors) will produce the full d-c output voltage swing of the BOP. If the selected control signal does not have the required amplitude or if the required control current cannot be supplied, the PREAMP "A" configuration can be altered to provide the proper interface for the application.

3-20 If, for example, the BOP d-c output is to be controlled by means of a bipolar, 1 volt, high impedance source, it can be connected to the BOP as shown in FIG. 3-7.

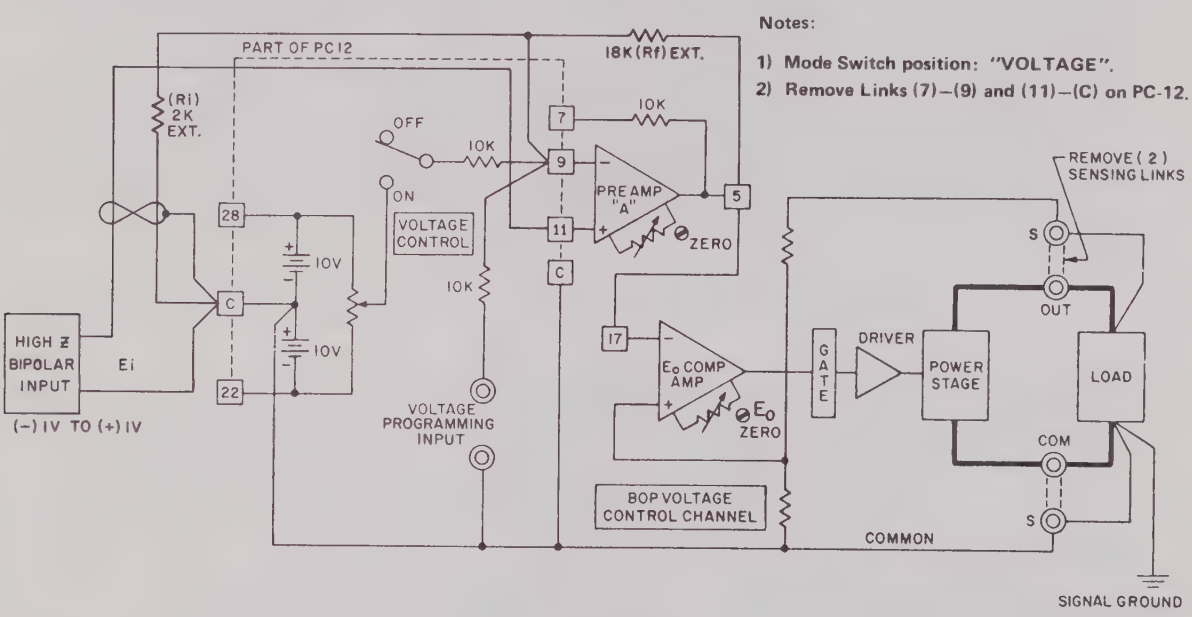


FIG. 3-7 BOP D-C OUTPUT VOLTAGE CONTROL WITH A HIGH IMPEDANCE. (±) 1V SIGNAL SOURCE.

3-21 As seen in FIG. 3-7, the original input feedback components of PREAMP "A" have been bypassed and are replaced by external resistors (small, metal film or wire-wound type resistors may be used and connected directly to the REAR PROGRAMMING CONNECTOR terminals as shown). PREAMP "A" is used in the non-inverting configuration. Its output voltage (the necessary BOP control voltage) is given by:

$$E_{o\,(\text{PREAMP "A"})} = E_i \frac{R_f + R_i}{R_i} \qquad \text{or } E_{o\,(\text{PREAMP "A"})} = \frac{18\text{K ohm} + 2\text{K ohm}}{2\text{K ohm}} = (\pm)\,10\text{V}$$

Consequently, as the BIPOLAR INPUT VOLTAGE (E_i) is controlled from (–) 1V over zero to (+) 1V, the BOP output voltage will follow over its specified range. Calibration of the system can be performed at the programming source, or the PREAMP "A" ZERO control can be used for the low end, while the feedback resistor (R_f = 18K ohm) can be trimmed to calibrate the high end of the range.

3-22 THE BOP AS AN AMPLIFIER

3-23 If, instead of the previously used d-c control signal, an a-c signal voltage is applied to the E_o PROGRAM INPUT, the BOP functions as a bipolar amplifier. As an amplifier, the BOP voltage gain is set on each BOP model so that (as before with the d-c control signal) a bipolar a-c input signal with an amplitude of 0V to 20V (peak-to-peak) will drive the BOP output through its specified (±) output voltage range. All other dynamic specifications are given in Section I, Table 1-3.

3-24 The BOP can be used to amplify, sum or scale a variety of waveshapes, some of which are illustrated in FIG. 3-8. All input signals are shown 180° out of phase with their corresponding output waveshapes. The latter can be readily produced in phase (i.e. with the output wave taking the same direction as the input signal) by addressing the non-inverting input of PREAMP "A" instead of the front panel E_o PROGRAM INPUT (Inverting).

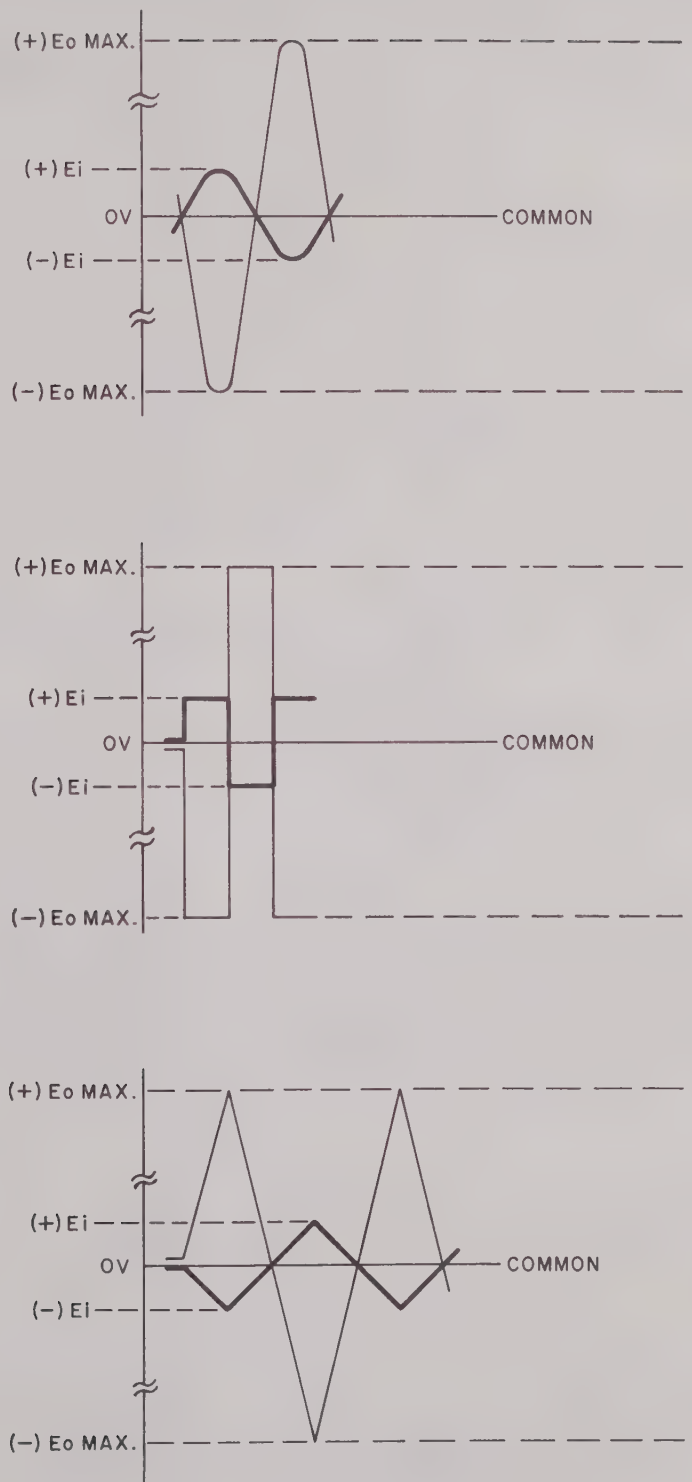


FIG. 3-8 GRAPHS OF POSSIBLE BOP INPUT/OUTPUT WAVE-SHAPES

3-25 The basic programming circuit with which the wave forms shown in FIG. 3-8 can be produced is shown in FIG. 3-9. Since all input signals in FIG. 3-8 are shown with a ± 10 volts amplitude, the basic programming circuit in FIG. 3-9 must be modified if the external signal source cannot produce 10 volts and if the full BOP output voltage swing is required.

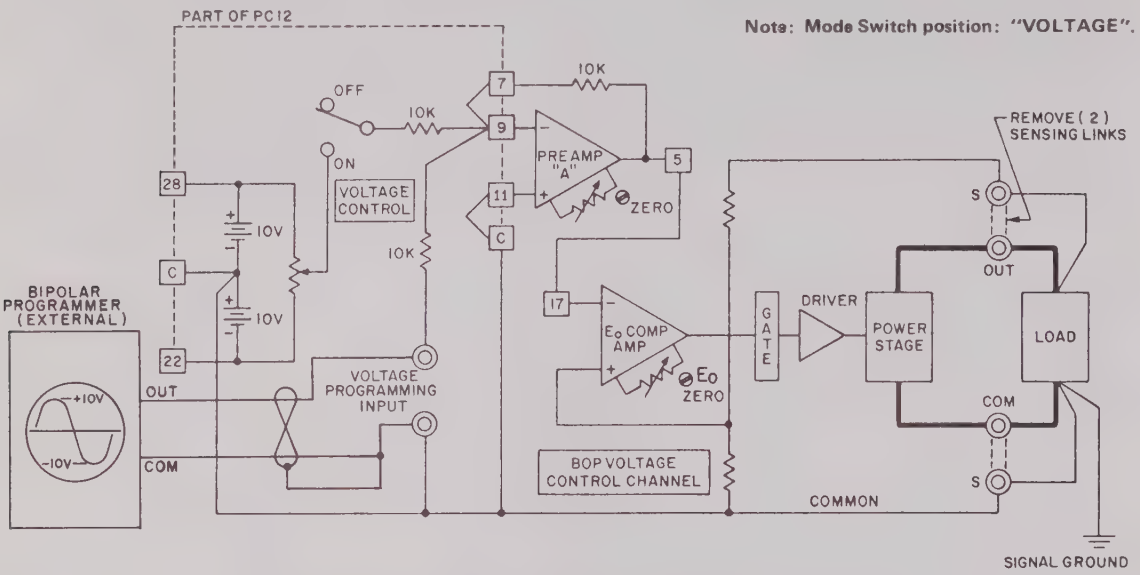


FIG. 3-9 BASIC PROGRAMMING CIRCUIT FOR USE OF THE BOP AS A BIPOLAR AMPLIFIER (VOLTAGE MODE)

3-26 If the EXT. PROGRAMMING SOURCE does not have sufficient amplitude to drive the BOP over its full output range, the gain of PREAMP "A" must be changed from the built-in value (one) to suit the application. To calculate the required components for the new gain requirement, the output equation for PREAMP "A" in the inverting configuration is used:

$$E_{o(\text{PREAMP "A"})} = -E_i\,(R_f/R_i)$$

where E_o (PREAMP "A") = ± 10V, and the values of R_f and R_i depend on the available amplitude of the programming source. If, for example, a ± 1 volt source is available, the ratio R_f/R_i must be 10, and the two resistor values can be 10K and 100K respectively. The built-in resistor (R_i = 10K) can be retained, and only R_f must be replaced with a 100K metal film (½ watt) unit. The necessary connections are illustrated in FIG. 3-10. Gain control (1 to 10) can be exercised by making R_f a rheostat instead of a fixed resistor.

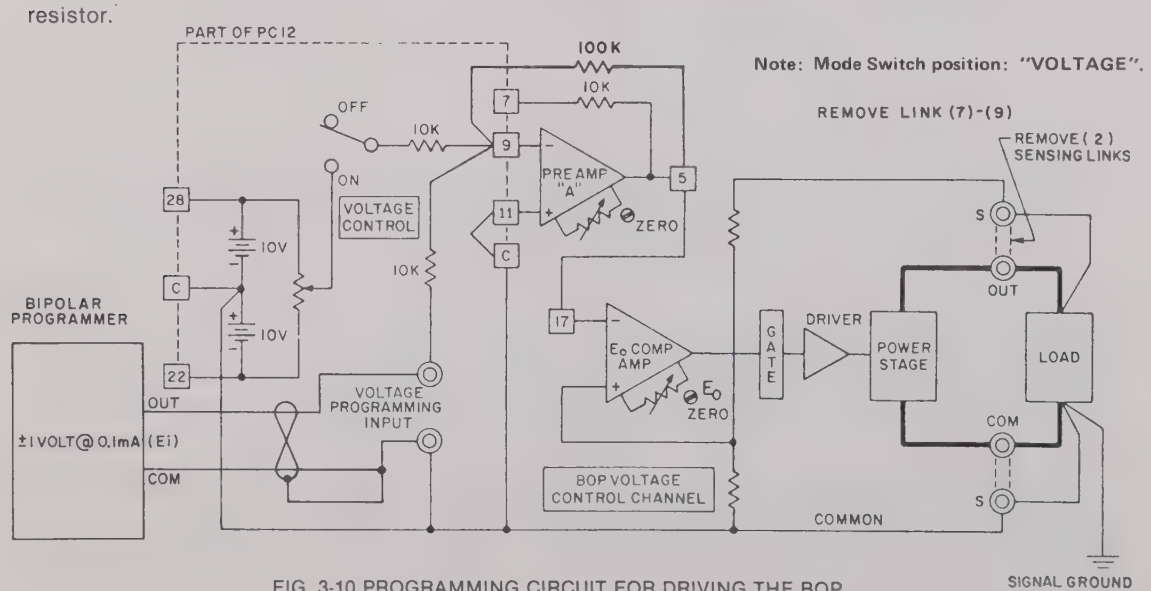


FIG. 3-10 PROGRAMMING CIRCUIT FOR DRIVING THE BOP OUTPUT VOLTAGE WITH A BIPOLAR (± 1V) SIGNAL

3-27 The non-inverting input of PREAMP "A" is used for applications where the external programming source has a high impedance and/or cannot supply the necessary drive current, or where a positive going output swing is desired for a positive going input signal. The necessary connections are illustrated in FIG. 3-11 for a PREAMP "A" gain of unity (with the built-in value for R_i retained and a short across R_f), although other gain configurations can be chosen, according to the output equation for the non-inverting configuration:

$$E_{o\ (PREAMP\ "A")} = \frac{R_f + R_i}{R_i}$$

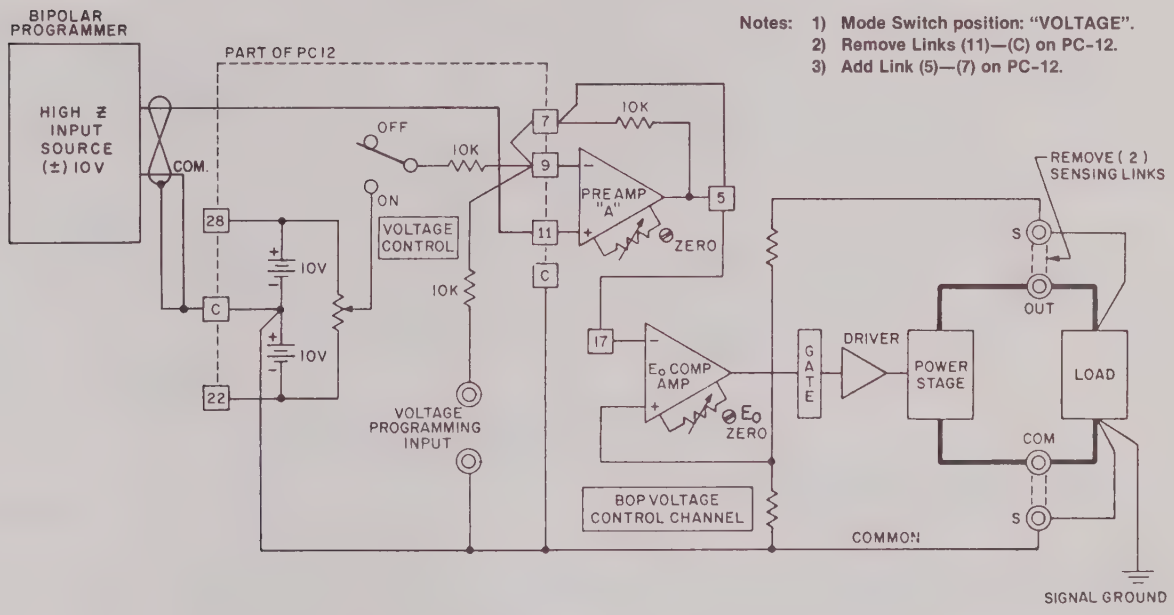


FIG. 3-11 PROGRAMMING CIRCUIT FOR DRIVING THE BOP OUTPUT VOLTAGE WITH A HIGH-IMPEDANCE SOURCE, USING THE NON-INVERTING INPUT OF PREAMP "A".

3-28 BOP OPERATION WITH REMOTE CONTROL OF THE CURRENT CONTROL CHANNEL

3-29 GENERAL: In the local (front panel) control mode, the BOP output current can be controlled by means of the CURRENT CONTROL, with the CURRENT CONTROL SWITCH closed, and the MODE SWITCH in the "CURRENT" position, over the full output range. The control potential (zero to (±)10V) is applied via PREAMP "B", operating with unity gain, to the I_o COMP. AMP which drives the POWER STAGE with a fixed gain as listed in Section I, Table 1-1. A d-c control signal from zero to (±)10 volts will, therefore, control the BOP output current through its specified range (refer to FIG. 3-12).

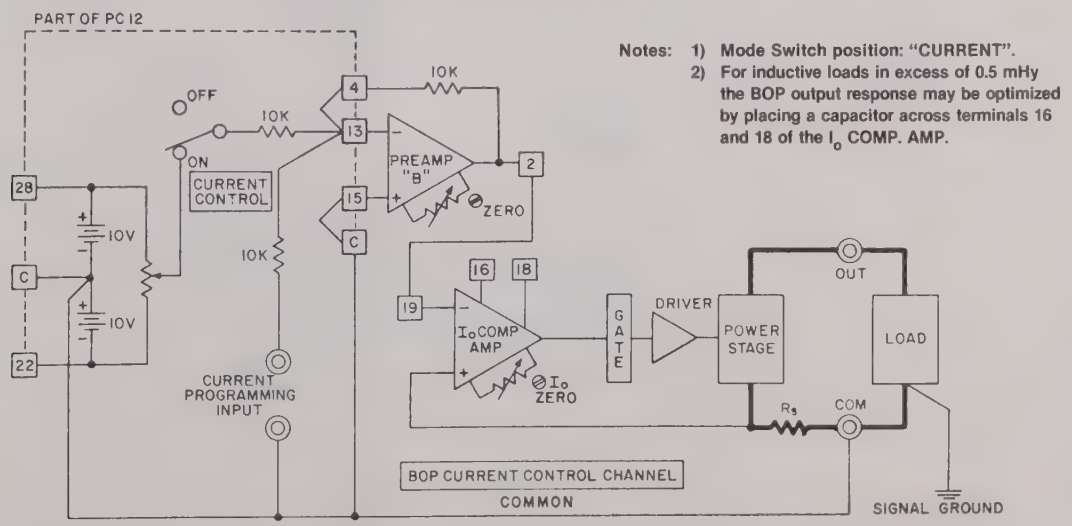


FIG. 3-12 LOCAL (FRONT PANEL) CONTROL OF THE BOP OUTPUT CURRENT WITH THE BIPOLAR CURRENT CONTROL

3-30 REMOTE CONTROL OF THE BOP CURRENT CHANNEL. Since the input signal requirements for the control of the BOP output current are the same as for programming the output voltage, and since the control circuitry of the current channel is almost identical to that of the voltage channel, all programming circuit descriptions for programming the output voltage of the BOP can be applied to current programming. The current programming circuits are illustrated in the following diagrams. Any comments, specifically applicable to current channel programming are noted on the diagrams. ***NOTE:*** *Adjust the "zero" output current point by means of the built-in ZERO control of PREAMP "B" or that of the I_o COMP. AMP.*

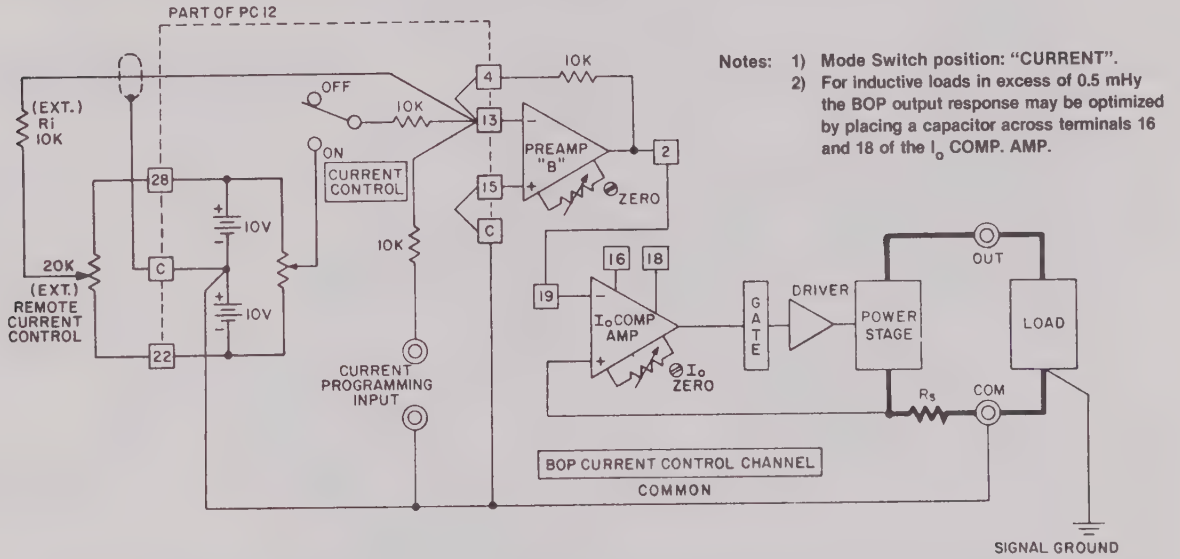


FIG. 3-13 REMOTE POTENTIOMETER CONTROL OF THE BOP OUTPUT CURRENT

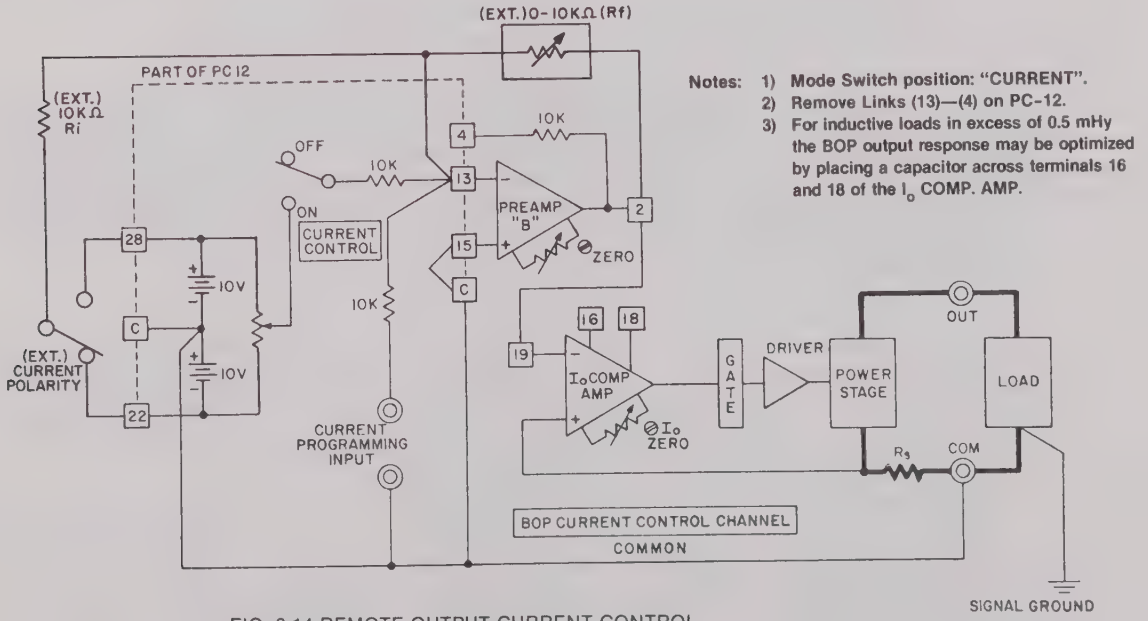


FIG. 3-14 REMOTE OUTPUT CURRENT CONTROL
BY MEANS OF A TWO-TERMINAL RESISTANCE.

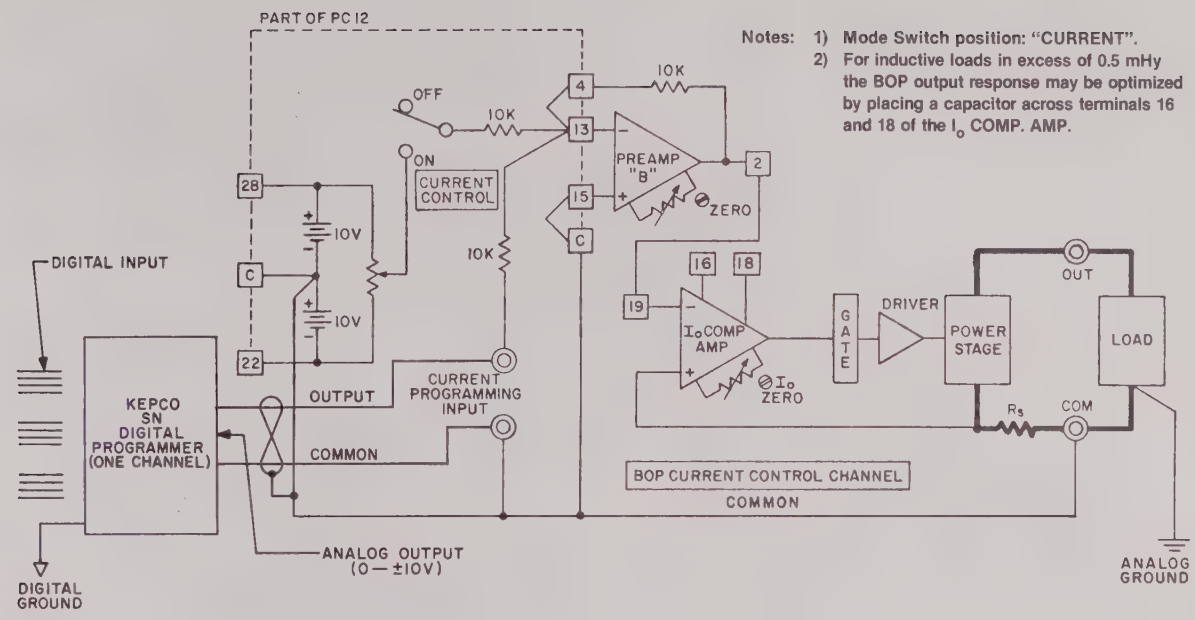


FIG. 3-15 DIGITAL CONTROL OF THE BOP OUTPUT CURRENT

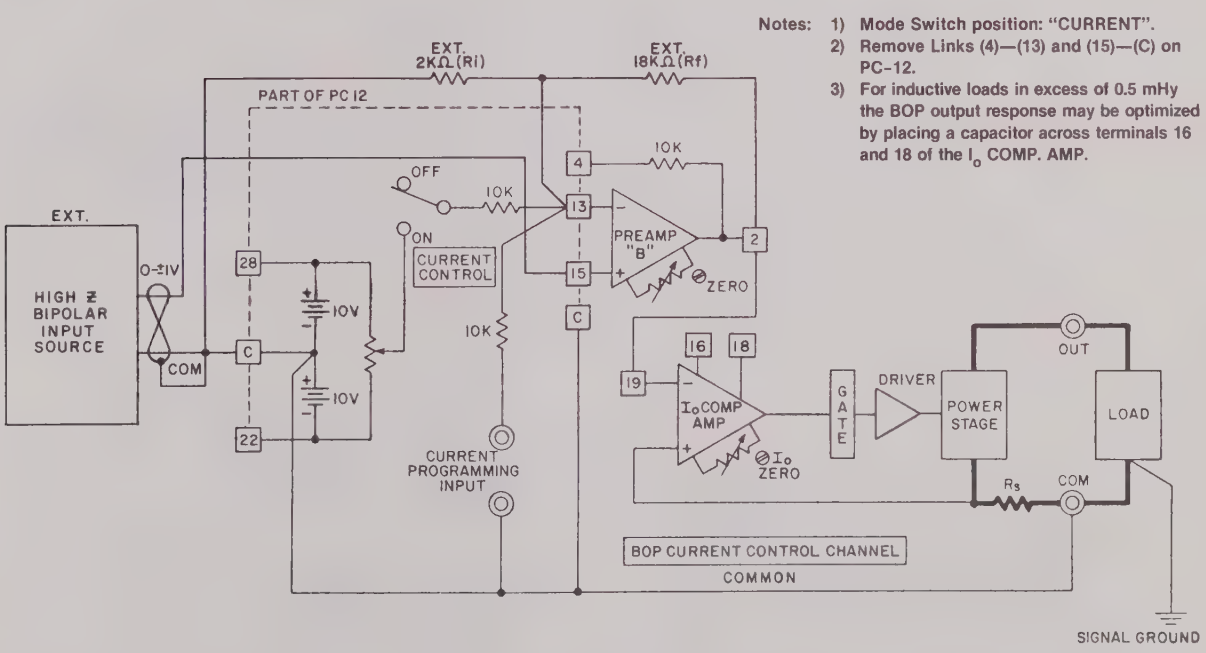


FIG. 3-16 BOP OUTPUT CURRENT CONTROL WITH A HIGH IMPEDANCE (±)1 VOLT SIGNAL SOURCE

NOTE: The non-inverting input of the Pre-amplifier is used to prevent loading of the input source.

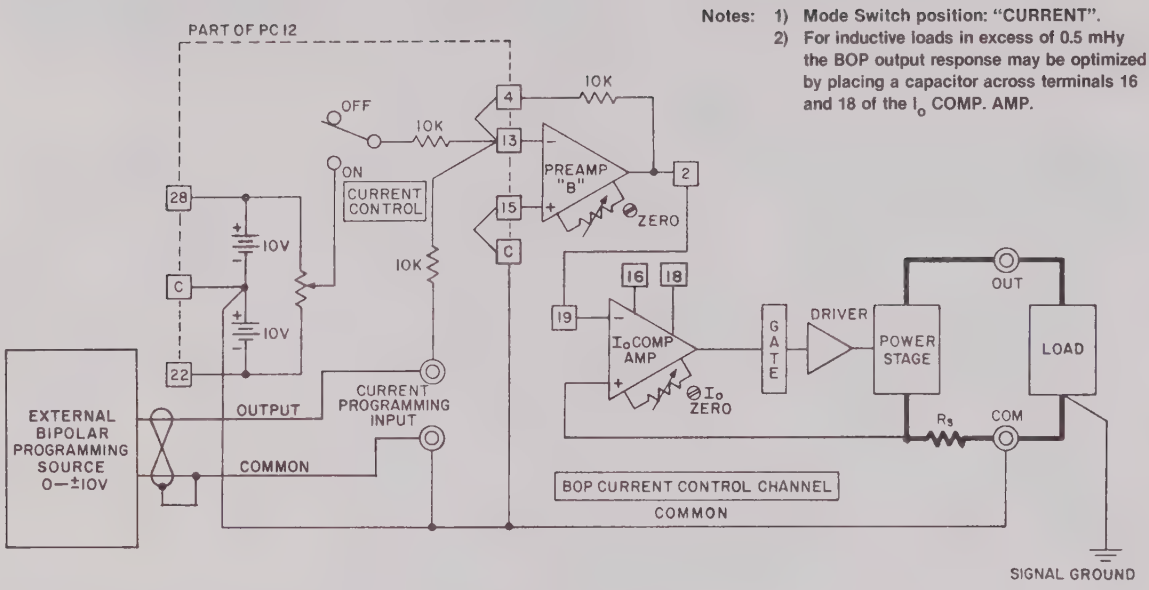


FIG. 3-17 BASIC PROGRAMMING CIRCUIT FOR USE OF THE BOP AS A BIPOLAR CURRENT-STABILIZED AMPLIFIER.

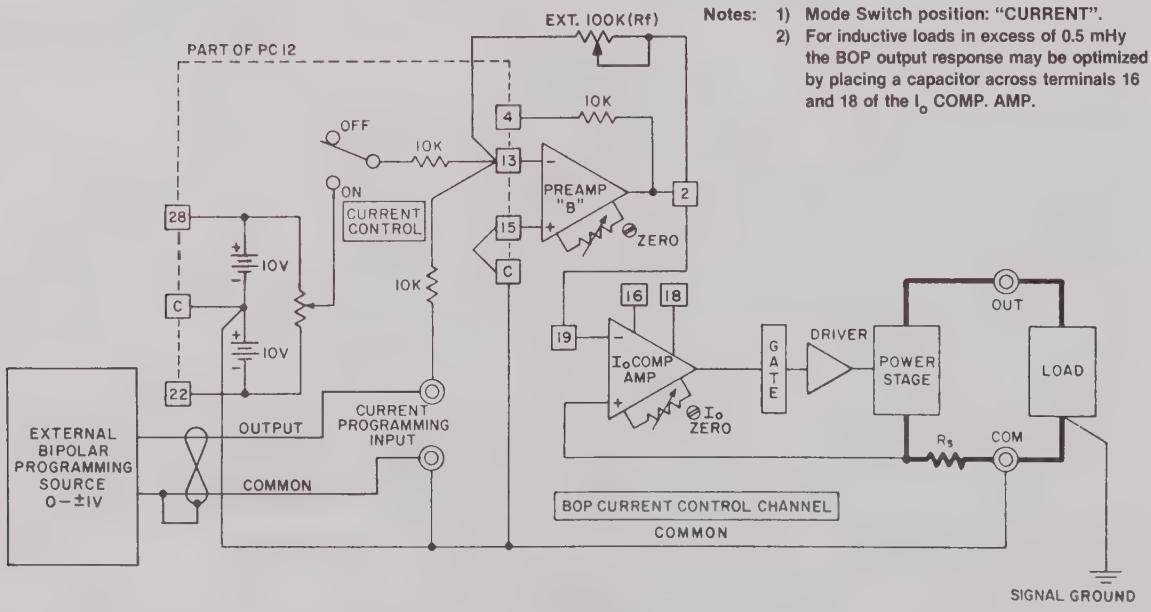


FIG. 3-18 PROGRAMMING CIRCUIT FOR DRIVING THE BOP OUTPUT CURRENT WITH A BIPOLAR SIGNAL LESS THAN ± 10V (EXAMPLE SHOWN: ± 1V SOURCE)

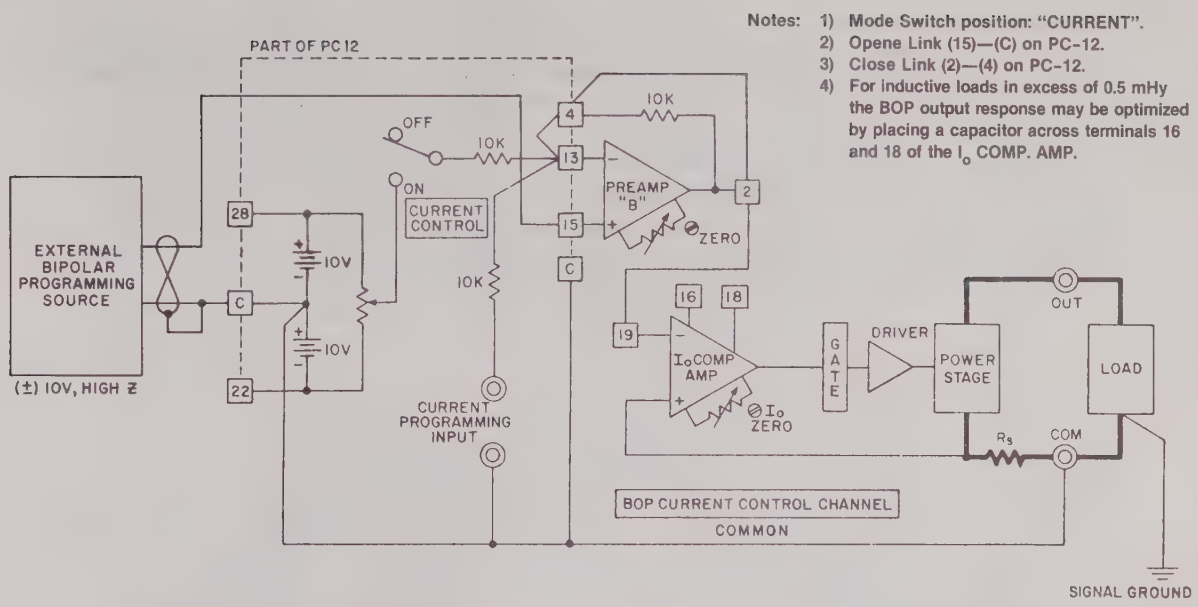


FIG. 3-19 PROGRAMMING CIRCUIT FOR DRIVING THE BOP OUTPUT CURRENT WITH A HIGH IMPEDANCE SOURCE

3-31 REMOTE CONTROL OF THE BOP CURRENT LIMIT (Refer to Section IV, FIG. 4-1.)

3-32 The output current is sensed by the current sensing resistor (R_s). The voltage drop across R_s is proportional to the output current value, and is amplified by a current sensing amplifier (not shown in FIG. 3-20) and is applied at the input to the (−) I_o LIMIT COMPARISON AMPLIFIER and to the (+) I_o LIMIT COMPARISON AMPLIFIER. In the local (front panel) control mode, as well as in the external control mode, a 0 to 10 volt signal, applied at the inverting inputs of the ± I_o LIMIT COMPARISON AMPLIFIERS, will control the current limit point over the entire output current range of each BOP model. For the internal (front panel) control mode, the control signal is derived across both 10 volt reference sources, applied by means of the ± I_o LIMIT controls to the internal ± I_o LIMIT AMPLIFIERS (both connected as 1:1 voltage followers) and directed to the respective inputs of the ± I_o LIMIT COMPARISON AMPLIFIERS. In the internal control mode, both ± I_o LIMIT AMPLIFIERS (EXT) are biased "off" by means of the 15V BIAS source.

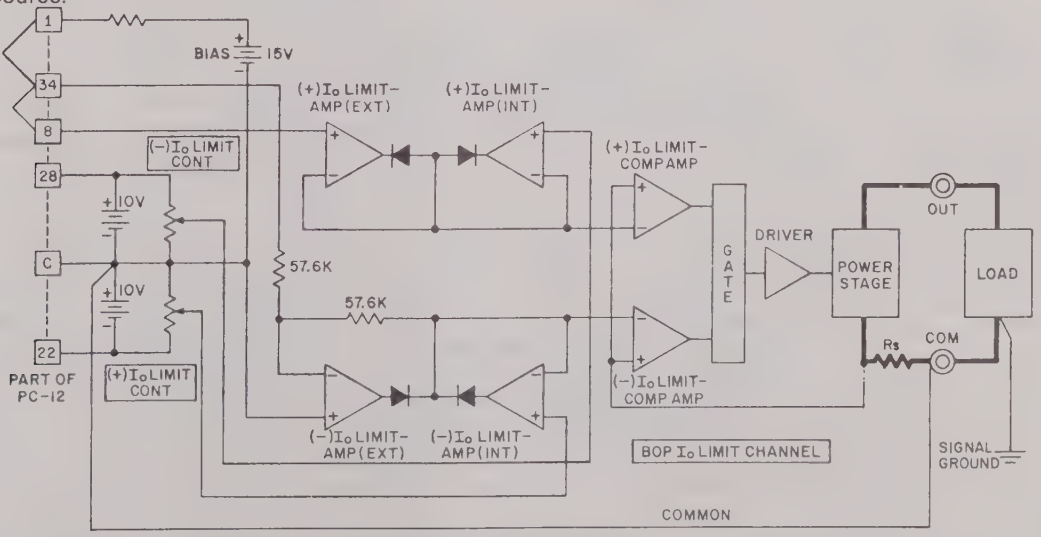


FIG. 3-20 LOCAL (FRONT PANEL) CONTROL OF THE BOP CURRENT LIMIT CIRCUIT

3-33 In the external control mode, the ± I_o LIMIT AMPLIFIERS (EXT) are disconnected from the 15V BIAS source (jumper 1-8 removed) and external 0-10V control signal is applied to terminals 8 and 34, with reference to COMMON. This control signal will program both, the negative as well as the positive current limit simultaneously and symmetrically over the BOP output current range (See FIG. 3-21). If individual control of the ± current limits is desired, the jumper 8-34 must be removed and separate control sources must be connected, 0-10 volts to pin 8 for the (+) I_o limit, and 0-10 volts to pin 34 for the (−) I_o limit, both with reference to COMMON (See Fig. 3-22).

NOTE: *The front panel ± I_o LIMIT controls serve as a back-up when external current limit programming is used. The controls should be set to a value slightly larger than the external current limits that are to be programmed.*

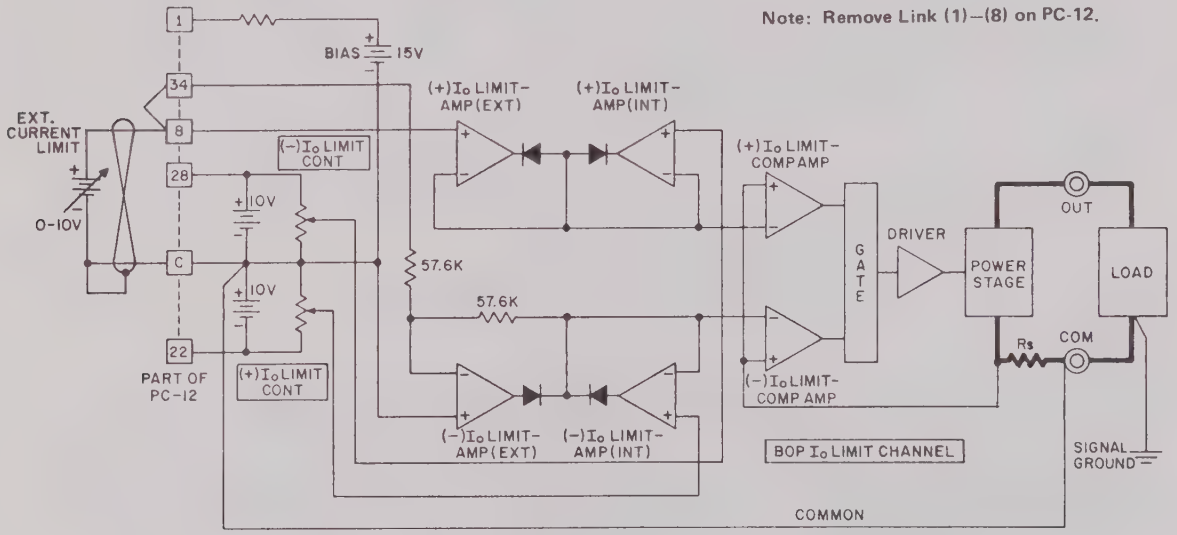


FIG. 3-21 SYMMETRICAL REMOTE CONTROL OF THE BOP CURRENT LIMITS

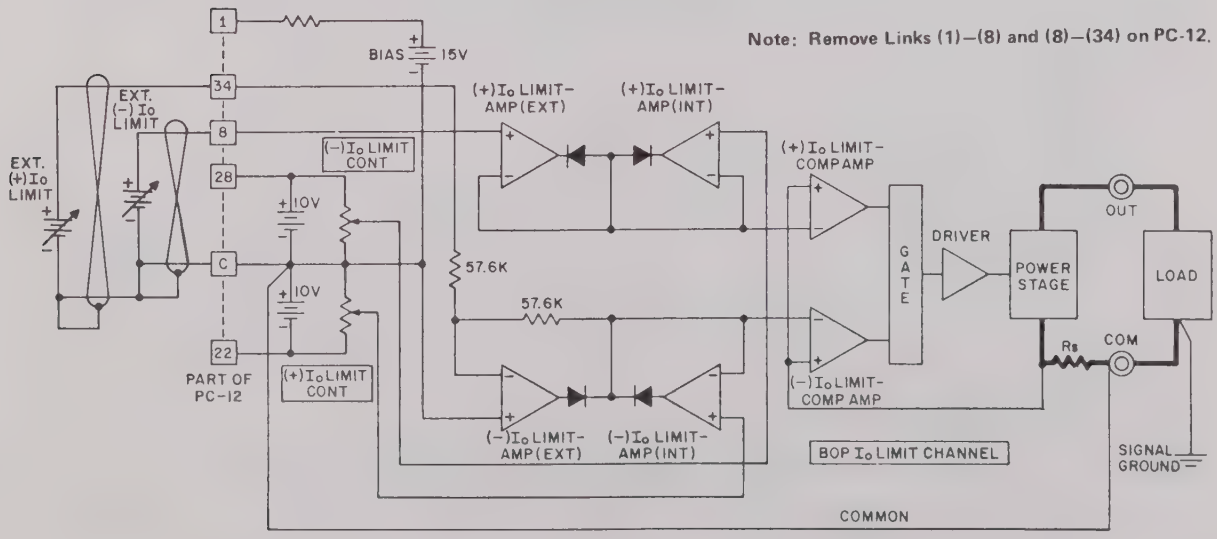


FIG. 3-22 INDEPENDENT REMOTE CONTROL OF THE BOP (+) I_o AND (−) I_o LIMITS

3-34 REMOTE CONTROL OF THE BOP VOLTAGE LIMIT

3-35 The BOP E_o LIMIT CIRCUIT in the local (front panel) control mode is shown in FIG. 3-23. The circuit functions in a similar manner as the I_o LIMIT CIRCUIT described previously (refer to Paragraph 3-31), except that the voltage limit feedback is derived by means of a voltage divider across the BOP output. The ± voltage limit can be remotely controlled symmetrically with a 0 to 10V d-c source, or the (+) and (−) voltage limit can be controlled independently by individual 0 to 10V d-c sources, The necessary circuit connections are illustrated in FIG.'s 3-24 and 3-25.

NOTE: *The front panel VOLTAGE LIMIT CONTROLS serve as a "back-up" when remote controlling the voltage limits on the BOP. The front panel VOLTAGE LIMIT CONTROLS should be set to their* ***maximum positions*** *if full range remote control of the BOP voltage limit is desired.*

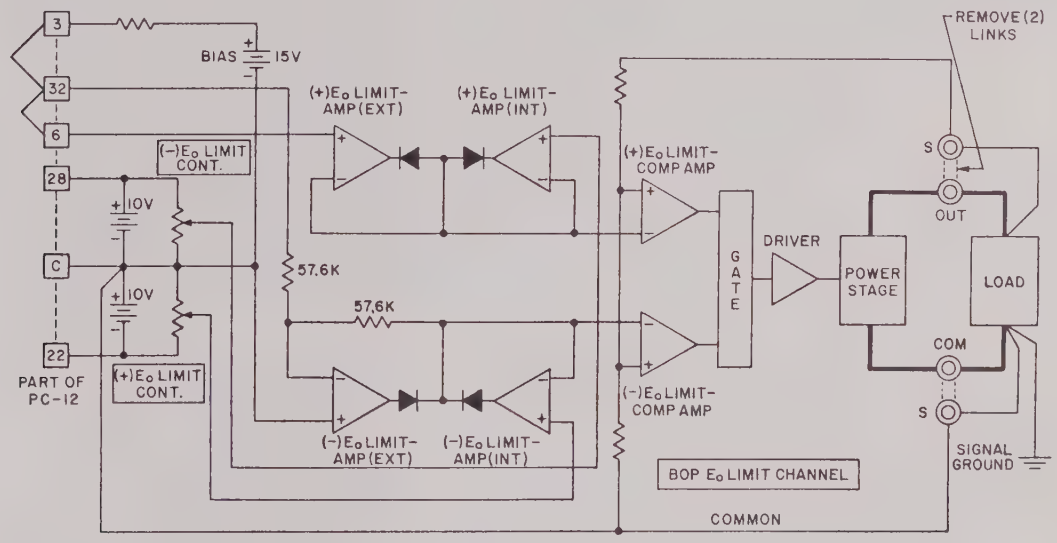


FIG. 3-23 LOCAL (FRONT PANEL) CONTROL OF THE BOP VOLTAGE LIMIT CIRCUITS

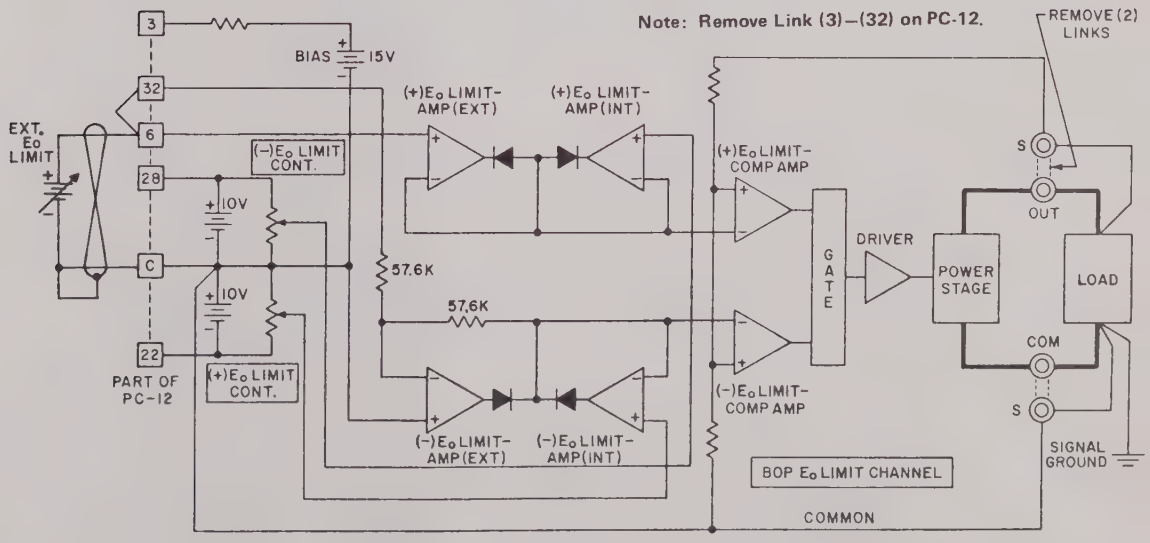


FIG. 3-24 SYMMETRICAL REMOTE CONTROL OF THE BOP VOLTAGE LIMIT CIRCUITS

Note: Remove Links (3)–(32) and (6)–(32) on PC-12.

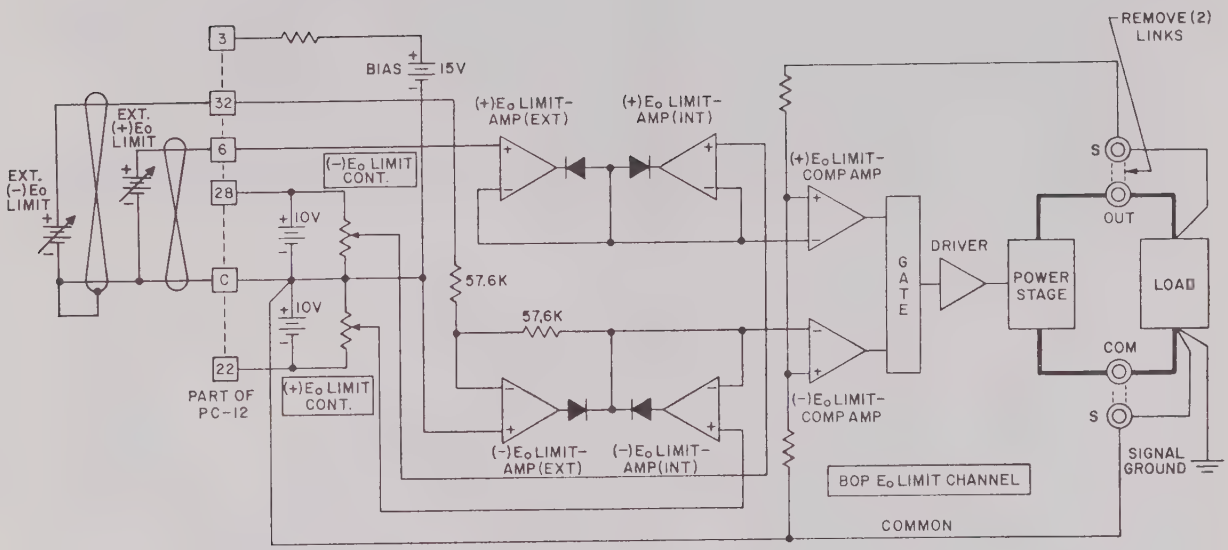


FIG. 3-25 INDEPENDENT REMOTE CONTROL OF THE BOP
(+) E_o AND (−) E_o VOLTAGE LIMIT CIRCUITS

3-36 SERIES AND PARALLEL CONNECTION OF BOP POWER SUPPLIES.

3-37 GENERAL. Voltage sources, such as batteries, cells or stabilized d-c power supplies can be readily series-connected, but normally, they can not be paralleled. Even minute differences in their terminal potential would cause large, damaging circulating currents. By complementary reasoning, current sources can easily be paralleled, but not series-connected. Fortunately, with practical stabilized power supplies these difficulties can be overcome in various ways.

3-38 There are two basic methods which are commonly used for the series or parallel connection of stabilized d-c power supplies. The first method is the "AUTOMATIC" series or parallel connection by which the power supply outputs are simply connected together, in series or parallel, as required. The individual supplies can now be adjusted to the load requirements. The "AUTOMATIC" method presents no problems as long as it is confined to SERIES connection with voltage sources, or to PARALLEL connection with current sources. As far as the BOP is concerned, the only thing to remember is to place the MODE switch into its proper position:

AUTO-SERIES CONNECTION: All BOP MODE SWITCHES TO "VOLTAGE"

AUTO-PARALLEL CONNECTION: All BOP MODE SWITCHES TO "CURRENT".

3-39 The second method for series or parallel connection of two or more units is the "MASTER/SLAVE" configuration, by which a designated MASTER supply controls the output of one or more SLAVE units. This control method permits control of the common output by a single unit - the MASTER. Since this method presents the least problems for either series or parallel connections and since it is readily implemented with BOP power supplies, it is the recommended method for this kind of operation and will be fully described below.

3-40 MASTER/SLAVE SERIES CONNECTION OF TWO BOP SUPPLIES, PROCEDURE:

1) Connect the BOP supplies as shown in FIG. 3-26. Set the MODE switches and the VOLTAGE CONTROL switches as directed in the set-up diagram, FIG. 3-26. Load-wire size should be as large as practicable and load-wire pairs should be twisted to keep the d-c resistance, as well as the inductance as low as possible. Use shielded cable for connecting the coupling resistor (R_T). Connect shield to common ground. Either the positive, or the negative output side of the system can be grounded.

2) Both BOP power supplies should be connected to the power line using a common circuit breaker. Alternatively, the BOP Circuit-Breaker Control Circuit, as described in Section IV, paragraph 4-25 can be used to interconnect both BOP's in such a way, that if one of them should fail, the other one is automatically shut down also.

3) The coupling resistor (R_T) should be either a wire-wound or a metal film unit with a low temperature coefficient. It is calculated by:

$$R_T \text{ (Kohms)} = E_{OM} \text{ (MAX) Volts - 10 Volts,}$$

where E_{OM} (MAX.) is the rated maximum output voltage of the BOP MASTER supply. This value of R_T will be able to drive the BOP SLAVE unit to its ($\pm$) maximum output voltage, as the BOP MASTER is controlled through its range.

4) Following the set-up procedures as described above, turn BOP's "on" and commence operation. The system as shown in the set-up diagram (FIG. 3-26) operates in the Voltage Mode, since the MASTER MODE switch is in "VOLTAGE" position. For operation in the Current Mode, transfer the MASTER MODE switch to "CURRENT".

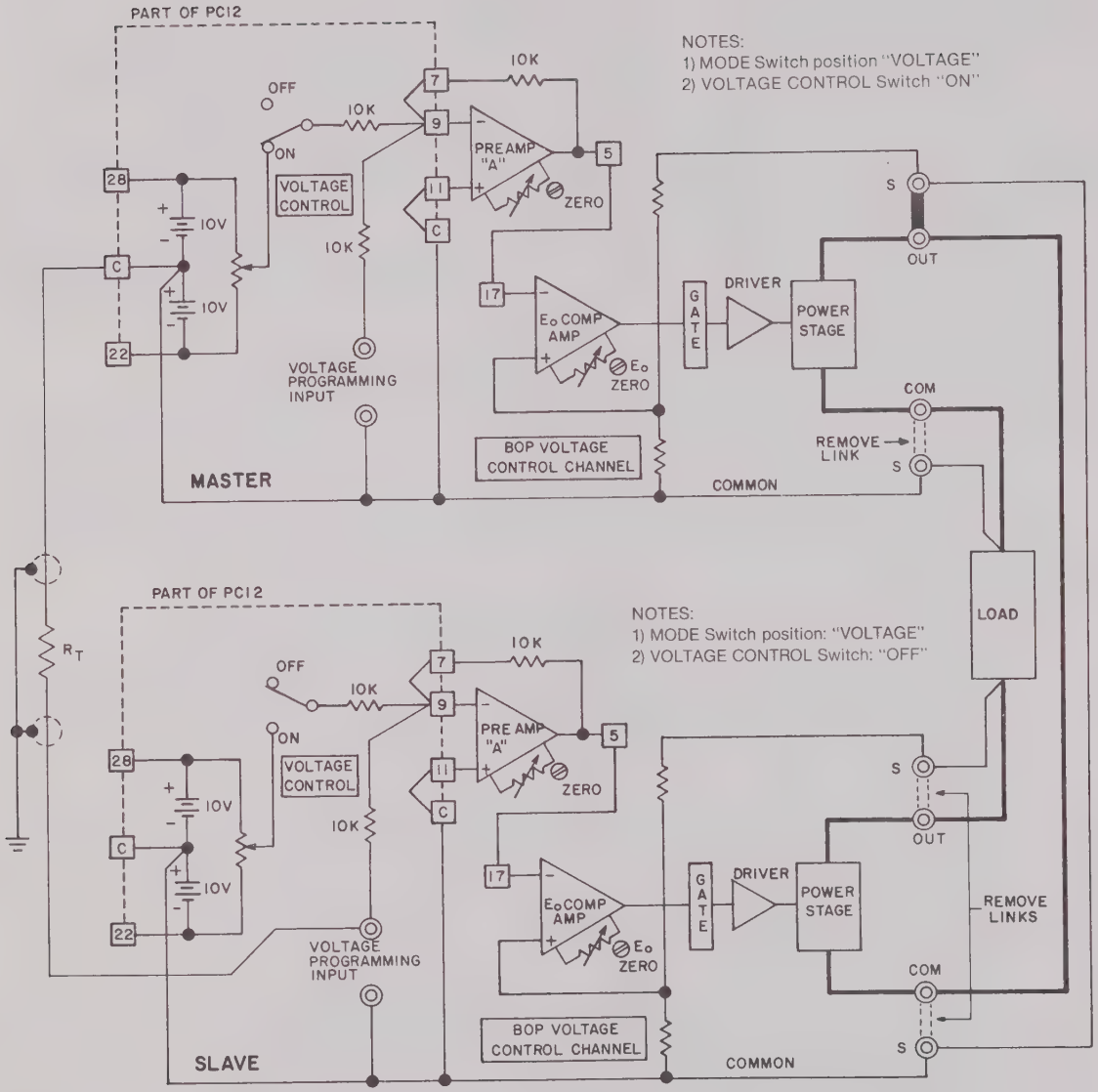


FIG. 3-26 MASTER/SLAVE SERIES CONNECTION OF TWO BOP POWER SUPPLIES, WITH ERROR SENSING AT THE COMMON LOAD.

NOTE: *Remove grounding network on SLAVE unit by opening the Link (4)-(5) on the rear barrier strip (TB201).*

3-41 MASTER/SLAVE PARALLEL CONNECTION OF TWO BOP SUPPLIES, PROCEDURE:

1) Connect the BOP supplies as shown in FIG. 3-27. Set the MODE switches and the VOLTAGE and CURRENT CONTROL switches as directed in the set-up Diagram, FIG. 3-27. Load-wire size should be as large as practicable and load-wire pairs should be twisted to keep the d-c resistance, as well as the inductance, as low as possible. Use shielded cable for the drive signal connection between the BOP's. Connect the shield to common ground. Either the positive or the negative output side of the system can be grounded.
2) Both BOP power supplies should be connected to the power line using a common circuit breaker. Alternatively, the BOP Circuit-Breaker Control Circuit, as described in Section IV, paragraph 4-25 can be used to interconnect both BOP's in such a way, that if one of them should fail, the other one is automatically shut down also.
3) Following the set-up procedure as described above, turn BOP's "on" and commence operation. The system as shown in the set-up diagram (FIG. 3-27) operates in the Voltage Mode, since the MASTER MODE switch is in "VOLTAGE" position. For operation in the current mode, transfer the MASTER MODE switch to "CURRENT".

3-42 MASTER/SLAVE SERIES OR PARALLEL CONNECTIONS FOR MORE THAN TWO BOP POWER SUPPLIES.

The concept of series connecting or paralleling two BOP power supplies can be extended to include interconnection of more than two BOP units. The limitations applying to the series-connection is the isolation limit of the BOP itself (500V), while that of the parallel connection is the load-wire size required for larger and larger loads.

3-43 To extend the concept of series connection to more than two BOP units, refer to FIG. 3-26. The BOP unit now designated the SLAVE becomes the new MASTER for the next BOP unit to be added and so on, up to the desired number of BOP's in series. Simply place the BOP outputs in series and connect a further coupling resistor (R_T) from the ***present*** SLAVE, terminal [C] to the ***new*** SLAVE, front panel VOLTAGE PROGRAMMING INPUT. Place the MODE switch on the BOP added to the series combination to VOLTAGE and the VOLTAGE CONTROL switch OFF.

3-44 To add more BOP units to the parallel system shown in FIG. 3-27, simply place the output leads of the unit to be added in parallel to the load. Set its MODE switch to CURRENT and its CURRENT CONTROL switch to OFF. Now connect another shielded cable from the BOP designated MASTER in FIG. 3-27, terminal [10] on PC-12, to the new BOP to be added, PC-12 terminal [19].

3-45 All series/parallel systems of BOP power supplies should be interconnected via the BOP Circuit Breaker Control Circuit, as described in Section IV, paragraph 4-25. This failure detection loop will shut down ***all*** BOP units in a series or parallel system if one of them fails.

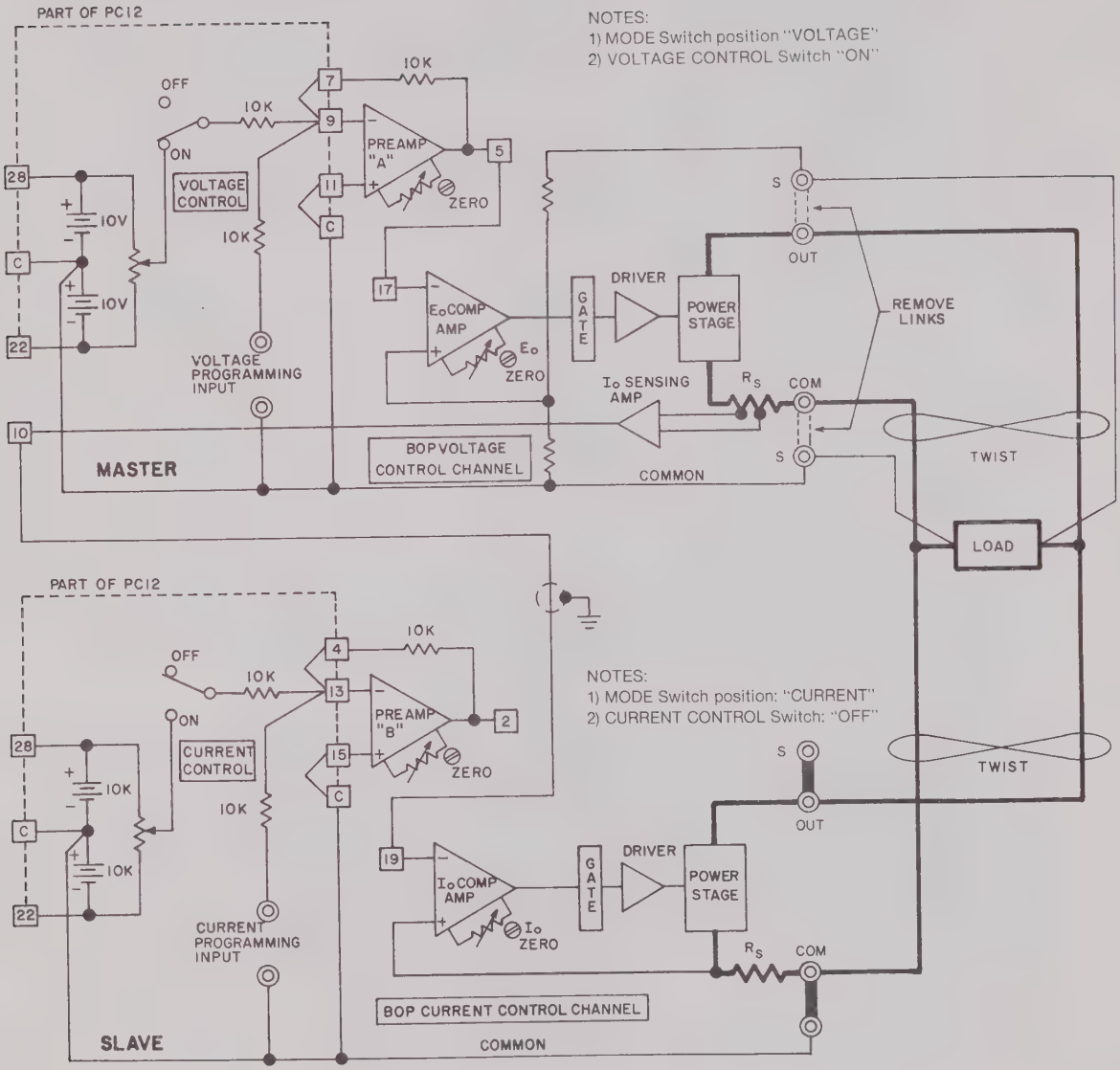


FIG. 3-27 MASTER/SLAVE PARALLEL CONNECTION OF TWO BOP POWER SUPPLIES

3-46 DIGITAL CONTROL OF BOP POWER SUPPLIES.

3-47 The output of the BOP power supply, that is, the output voltage and the output current limit, with the BOP in the Voltage Mode of operation, or the output current and the output voltage limit with the BOP in the Current Mode of operation, may be digitally controlled by means of a Kepco Digital Programmer. Kepco Digital Programmers accept data from serial or parallel data buses and convert this data to an analog output voltage which, in turn, controls the output parameters of the connected BOP power supply.

3-48 The following paragraphs present a brief overview of the available Kepco programming interfaces. Each of these devices is delivered with its own instruction manual, which provides the necessary details for operation, programming and maintenance.

3-49 Common features of all Kepco programming interfaces include optical isolation of digital input and analog output, dual, selectable output ranges of 0 to 1V or 0 to 10V, and output polarity control, making them suitable for unipolar or bipolar power supply programming.

3-50 Since the output of all Kepco Digital Programmers is a linear, analog voltage of either 0 to 1V, or 0 to 10V, depending on the range selected, all programming examples in this section (Section III) which show an external programming source may be used for digitally programming the BOP power supply. Although the given examples show single function applications only, simultaneous programming of several output functions, such as voltage control with current limit or current control with voltage limit may be performed with all digital programmers having more than one output channel.

3-51 KEPCO DIGITAL PROGRAMMERS.

3-52 The SN GROUP consits of the following models:

	MODEL SN 488-				MODEL SN 500-			
	121	122	031	032	121	122	031	032
CHANNELS	1	2	1	2	1	2	1	2
INPUT DATA CODE	ASCII/HEX		ASCII/BCD		ASCII/HEX		ASCII/BCD	
RESOLUTION	12 bit		3 DIGIT		12 bit		3 DIGIT	
OUTPUT	0-1V or 0-10V		0-1V or 0-10V		0-1V or 0-10V		0-1V or 0-10V	

3-53 SN 488 SINGLE OR DUAL CHANNEL DIGITAL PROGRAMMERS

3-54 The Kepco SN 488 Programmers were designed to operate on the GPIB (IEEE 488) bus. Once addressed by the controller with their unique, presetable address code and placed in the Data Mode, they accept a sub-set of the 7-bit ASCII code ("0" through "9", "A" through "F") having the following data format and sequence: NCVVV (ASCII)

Byte 1 — N = Channel Select, "1" or "2".

Byte 2 — C = Control Character: C = "0" Pos. Out, High Range

Byte 3 — VVV = Output Volts C = "1" Neg. Out, High Range

Byte 4 — as a percentage of full C = "2" Pos. Out, Low Range

Byte 5 — scale C = "3" Neg. Out, Low Range

3-55 Data transfer is byte-serial. The output voltage bytes (3 to 5) may be encoded in hexadecimal notation (000 to FFF) for models SN 488-121 and SN 488-122 and in BCD notation (000 to 999) for SN 488-031 and SN 488-032. The data transfer time is approximately 60μsec.

3-56 SN 500 SINGLE OR DUAL CHANNEL DIGITAL PROGRAMMERS

3-57 The Kepco SN 500 programmers were designed to operate on bit parallel data buses. The SN 500 accepts either positive or negative logic (selectable) on its input port. The SN 500 programmer is terminated with a 50-pin edge connector with pin-outs as shown below (See paragraph 3-59). The magnitude field input data may be BCD for SN 500-021 and SN 500-022 or BINARY for SN 500-121 and SN 500-122.

3-58 Data transfer is bit-parallel and is controlled by the STROBE pulse and the internally created BUSY signal following each STROBE (externally applied, 2μsec min.). Data transfer time is approximately 35μsec., although the data lines are free for other purposes, following the 2μsec. STROBE.

3-59 INPUT/OUTPUT CONNECTOR, PIN-OUT.

A) PIN 2 — SERIAL INPUT
PIN 4 — SERIAL OUTPUT
PIN 6 — SERIAL OUTPUT

WIRE JUMPER FOR NEGATIVE LOGIC

WIRE JUMPER FOR POSITIVE LOGIC (SUPPLIED)

Pins 2, 4 and 6 serve to select either POSITIVE LOGIC (L = 0, H = 1) by placing the jumper from pin 2 to pin 6, or NEGATIVE LOGIC (L = 1, H = 0) by placing the jumper from pin 2 to pin 4. The SERIAL INPUT may also be used for other purposes and may be syncronized by means of the SHIFT CLOCK output.

B)

PIN 8 — RANGE, CHANNEL 1	L = HIGH RANGE (0-10V)	H = LOW RANGE (0-1V)
PIN 10 — POLARITY, CHANNEL 1	L = POSITIVE OUTPUT	H = NEGATIVE OUTPUT
PIN 12 — RANGE, CHANNEL 2	L = HIGH RANGE (0-10V)	H = LOW RANGE (0-1V)
PIN 14 — POLARITY, CHANNEL 2	L = POSITIVE OUTPUT	H = NEGATIVE OUTPUT

All four RANGE and POLARITY selection terminations have been provided for manual preselection of range and polarities on both channels. If RANGE and POLARITY are machine controlled, only pins 8 and 10 are needed, since a CHANNEL SELECTOR command is required to preselect each channel. ***NOTE:*** *Pin 12 should be connected to pin 8 while pin 14 should be connected to pin 10. If, however, the application calls for fixed polarity and range, the appropriate pins can be hardwire according to the requirements.*

C) MAGNITUDE FIELD, DATA INPUT PINS:

PINS:	16	18	20	22	24	26	28	30	32	34	36	38
BITS:	12 MSB	11	10	9	8	7	6	5	4	3	2	1 LSB
DECADE	10^{-1}				10^{-2}				10^{-3}			
BCD	8	4	2	1	8	4	2	1	8	4	2	1

D) PIN 40 D-C LOGIC SUPPLY OUTPUT, 5V at 20mA maximum. May be used to connect pull-up resistors for establishing pre-wired logic states or to drive external logic within the given rating.

E) PIN 42—$\overline{\text{STROBE}}$. The negative going edge of the strobe signal (H→L) enables the loading of the Temporary Storage Registers with the data presented on the data pins. *The minimum duration of $\overline{\text{STROBE}}$ must be 2μsec.*

F) PIN 44—BUSY (H = BUSY, L = NOT BUSY). This output delivers a status signal to the bus. On the first clock transition (H→L), following the STROBE signal, the BUSY line goes high (H) and remains high until the first clock transition (H→L) following data transfer (approximately 35μsec.), indicating the SN 500 is ready to accept new data.

G) PIN 46—CHANNEL SELECT (H = CHANNEL 1, L = CHANNEL 2).

H) PIN 48—$\overline{\text{SHIFT CLOCK}}$. This output is used to synchronize the external SERIAL INPUT, if used.

J) PIN 50—SHIELD (CHASSIS). Chassis and Case connection of the SN 500.

K) PINS 1 thru 49 (Odd No.'s): LOGIC GROUND and LOGIC SUPPLY COMMON.

3-60 THE SNR PROGRAMMING SYSTEM

3-61 The Kepco SNR 488 Programming System consists of a full-rack housing with built-in interface card for the GPIB (IEEE 488) bus and several optional plug-in cards, each able to control 2 channels with a common connection.

3-62 The Model SNR 488-8 housing can accomodate eight (8) plug-in cards, while Model SN 488-4 seats four (4) cards and in addition has room for either two Kepco quarter-rack or one half-rack size power supply. Each housing is connected to the bus via a single cable, which serves all plug-in cards. Each SNR housing has a device address selector switch, while individual cards addresses are handled by means of the input command string to the SNR and a presetable address selector switch for each card.

3-63 SNR 488 programmers, when connected to the bus, addressed by the controller with their unique, presetable address code and placed in the data mode, accept a sub-set of the 7-bit ASCII code ("0" through "9", "A" through "F" and " = "), having the following data format and sequence: N = CVVVIII, each symbol representing an ASCII character, for a total of 9 bytes:

Byte 1 — N = Address Byte, card address

Byte 2 — "Equal" sign, delimiter

Byte 3 — Control Character C: determines RANGE and POLARITY for both, CHANNEL A and CHANNEL B Coded with ASCII characters "0" through "F", see SNR-488 Instruction Manual

Byte 4, Byte 5, Byte 6 — VVV = Output Quantity, Channel A

Byte 7, Byte 8, Byte 9 — III = Output Quantity, Channel B

3-64 Data transfer on the GPIB (IEEE 488) is byte-serial. The output quantity bytes (VVV and III) are encoded in hexadecimal notation for Model SN 488-B cards and in BCD notation for Model SN 488-D cards. Encoding ranges are 000 to FFF and 000 to 999 respectively. Data transfer time is approximately 60μsec.

3-65 THE BIT PROGRAMMING CARDS

3-66 These cards are inserted into an existing slot in the BOP series of Kepco power supplies. They convert the BOP into a stand-alone, digitally programmable power source. The card may be field-installed by the user, or the BOP may be ordered with the BIT card factory installed.

3-67 There are four (4) BIT models available. Two (2) of them, Models BIT 488-B and BIT 488-D are for operation of the BOP on the GPIB (IEEE 488) bus. The other two (2), Models BIT 500-B and BIT 500-D are for operation of the BOP on parallel data buses. Each BIT card controls the BOP's main channel and limit channel. Depending on the BOP's operating mode selection, either Output Voltage and Current Limit (Voltage Mode) or Output Current and Voltage Limit (Current Mode) can be controlled simultaneously.

3-68 THE BIT 488 DUAL CHANNEL DIGITAL PROGRAMMING CARDS.

3-69 The BIT 488 programming cards were designed to operate on the GPIB (IEEE 488) bus. Once addressed by the bus controller with their unique, presetable address code, they are placed in the Data Mode and accept a subset of the 7-bit ASCII code ("0" through "F").

3-70 The BIT 488 card requires the following data format and sequence: CMMMLL (ASCII).

Byte 1 — Control Character: C - determines BIT output range, polarity and BOP operating mode. ASCII DIGITS "0" through "7". See BIT 488 Instruction Manual

Byte 2, Byte 3, Byte 4 — Main Channel Output

Byte 5, Byte 6 — Limit Channel Output

3-71 Data transfer is byte-serial. The Main channel field (MMM) may be encoded in hexadecimal notation (000 to FFF) for BIT 488-B models or in BCD notation (000 to 999) for BIT 488-D models. Data transfer time is approximately 60μsec.

3-72 **THE BIT 500 DUAL CHANNEL DIGITAL PROGRAMMING CARDS.** The BIT 500 programming cards were designed to operate on bit-parallel data buses. These cards expect either positive or negative logic (selectable) at their input port. Once installed in the BOP, they are terminated by a 50-pin edge connector with pin-outs as shown in paragraph 3-74. The magnitude field for the MAIN CHANNEL and for the LIMIT CHANNEL is to be binary encoded for Model BIT 500-B and BCD encoded for Model BIT 500-D.

3-73 Data transfer is bit-parallel and is controlled by the externally applied STROBE pulse (2μsec. min) and the internally created BUSY signal, following each strobe. Data transfer time is approximately 35μsec., although the data lines are free for other purposes, following the 2μsec. STROBE.

3-74 INPUT/OUTPUT CONNECTOR, PIN-OUT FOR BIT 500.

NOTE: *All input commands are with reference to LOGIC GROUND.*

A) PIN 5 — SERIAL INPUT
PIN 1 — SERIAL OUTPUT
PIN 3 — SERIAL OUTPUT

Pins 1, 3 and 5 serve to select either POSITIVE LOGIC (L = 0, H = 1) by placing the jumper from pin 5 to pin 3, or NEGATIVE LOGIC (L = 1, H = 0), by placing the jumper from pin 5 to pin 1. The selection of POSITIVE or NEGATIVE logic applys only to DATA, POLARITY and RANGE signals.

B) Pin 17—Control (LOC/REM), H = REMOTE, L = LOCAL. Selects either local (FRONT PANEL) or remote (BUS) control of the BOP.

NOTE: *THIS PIN MUST BE HIGH (H) FOR REMOTE, (BUS) CONTROL OF THE BOP.*

C) Pin 15—MODE (V/I), H = CURRENT Mode, L = VOLTAGE Mode. Determines BOP operating mode. Designates the Main Channel to Voltage Control, Limit Channel to Current Limit Control.

D) Pin 13—RANGE (HI/LO), H = Low Range (0-1V), L = High Range (0-10V). Selects Main Channel output range.

E) Pin 11—POLARITY (+/−), H = Negative, L = Positive, Selects Main Channel output polarity with reference to ANALOG GROUND.

F) Pin 9 d-c LOGIC SUPPLY OUTPUT, 5V at 20 mA maximum. May be used to connect pull-up resistors for establishing pre-wired logic states or to drive external logic within the given ratings.

G) Pin 7—$\overline{\text{STROBE}}$. The negative going edge signal (H→L) enables the loading of the Temporary Storage Registers with the data presented on the data pins. The minimum duration of $\overline{\text{STROBE}}$ must be 2μsec.

H) Pin 47—BUSY (H = busy, L = not busy). This output delivers a status signal to the bus. On the first clock transition (H→L), following the $\overline{\text{STROBE}}$ signal, the BUSY line goes high (H) and remains high until the first clock transition (H→L), following data transfer (approximately 50μsec.), indicating the BIT 500 is ready to accept new data.

J) Pin 49—SHIELD (CHASSIS). Chassis and Case connection of the BIT 500.

K) Pins 37,39,41,43,45 LOGIC GROUND, COMMON, 5V LOGIC SUPPLY.

L) MAGNITUDE FIELD, MAIN CHANNEL

PINS:	2	4	6	8	10	12	14	16	18	20	22	24
BITS: (BIT 500-B)	12 MSB	11	10	9	8	7	6	5	4	3	2	1 LSB
DECADE (BIT 500-D)	10^{-1}				10^{-2}				10^{-3}			
BCD	8	4	2	1	8	4	2	1	8	4	2	1

M) MAGNITUDE FIELD, LIMIT CHANNEL

PINS:	34	36	38	40	42	44	46	48
BITS: (BIT 500-B)	8 MSB	7	6	5	4	3	2	1 LSB
DECADE (BIT 500-D)	10^{-1}				10^{-2}			
BCD	8	4	2	1	8	4	2	1

3-75 THE KEPCO MODEL TLD 488-16 INTERACTIVE DIGITAL PROGRAMMER.

3-76 The Kepco Model TLD 488-16 was designed to operate on the GPIB (IEEE 488) bus as a LISTENER/TALKER. It is configures as a standard rack card-cage, containing a micro-computer with bus interface, status monitor for catastrophic error reporting via a discrete line to the controller and an on-board parallel peripheral interface for optional load isolations relays.

3-77 The Kepco TLD 488-16 accepts up to four plug-in programming boards, either the Kepco Model TL 488-4A for Kepco ATE power supplies, or the TL 488-4B for Kepco BOP power supplies, or a mixture of these two models. Each board can control up to four (4) power supplies, so that a maximum of sixteen (16) power supplies may be digitally programmed via the TLD output ports, using only a single GPIB bus connection.

3-78 When using TL 488-4B programming cards for BOP power supplies, each BOP must be equipped whith an optional Kepco interface card, Model PCA X-3, which is installed inside the BOP. When using TL 488-A programming cards for ATE power supplies, each ATE is connected to the TLD 488-16 via a unique interface connector, Model PCA X-X, model number depending on ATE model designation. These PCA devices have the function of informing the TLD about the parameters of the connected power supplies.

3-79 Communications between the TLD 488-16 and the system controller in the COMMAND mode follow the GPIB (IEEE 488) protocol, with the TLD 488-16 implementing the following functions:

GPIB FUNCTION	SUBSET SYMBOL	COMMENTS
Source handshake	SH1	—
Acceptor handshake	AH1	—
Talker	T6	Basic talker, serial poll, unaddress if MLA
Listener	L4	Basic listener unaddress if MTA
Service request	SR1	—
Device clear	DC1	—

3-80 Communications between the TLD 488-16 and the system controller in the DATA mode, use elements of the CONTROL INTERFACE INTERMEDIATE LANGUAGE (CIIL). The statement syntax and operation codes of CIIL are encoded using the 7-bit ASCII character set and are briefly described below[1].

1) FNC - function op-code

   SYNTAX: FNC DCS :CHnn

   This operator, with the operands DCS and :CHnn is used at the start of each set-up sequence. The "DCS" operand is a CIIL "noun" and describes the type of device being set-up (DCS = d-c source, power supply). The :CHnn operand is used in the set-up of all devices and indicates the port or channel number of the TLD 488-16 in our case.

2) SET - set-up code

   SYNTAX: SET VOLT (value nnn)

   The SET command string is used to specify a characteristic of the device "DCS" specified in the FNC command string. The first operand (VOLT) indicating that characteristic. Possible operands for this field when programming the TLD 488-16 are: VOLT, CURR, VLTL, CURL. The second operand (value) which may be encoded in ASCII integer, decimal or scientific notation.

3) STA - status op-code

   SYNTAX: STA

   This op-code command the device to report its current operating status. It should be sent by the system controller after each set-up command string. There are no operands associated with this op-code.

4) RST - reset op-code

   SYNTAX: RST DCS :CHnn

   The RST command string resets the device at :CHnn to zero and opens the relays if used.

[1] For more details, refer to the TLD 488-16 OPERATOR'S MANUAL.

3-81 CIIL TRANSMISSION FORMAT.

3-82 The sequence of commands which address a specific power supply at port 0, set its voltage to 10V, its current limit to 2A and its subsequent reset is illustrated below:

TRANSMISSION 1: FNC sp DCS sp :CH00 sp (set-up)
SET sp VOLT sp 10 sp
SET sp CURL sp 2 cr lf

TRANSMISSION 2: STA cr lf (STATUS CHECK)

TRANSMISSION 3: RST sp DCS sp :CH00 cr lf (shut-down)

NOTE 1: *sp = ASCII (space or blank), cr = ASCII (carriage return) lf = ASCII (line feed).*

NOTE 2: *The individual CIIL statements of transmission 1 are shown on separate lines for readability only. In actuality they are concacenated into a single ASCII string.*

SECTION IV—THEORY OF OPERATION

4-1 GENERAL

4-2 This section contains a brief analysis of the BOP circuitry by means of a simplified circuit diagram, a discussion of the error equation and its application, and a circuit description based on the Main Schematic Diagram.

4-3 SIMPLIFIED DIAGRAM ANALYSIS (REFER TO FIG. 4-5)

4-4 The BOP Bipolar Operational Power Supply can be described as a stabilized d-c voltage or current source with either local (front panel) or remote control of its output. Its wide band characteristics permits operation as an amplifier, with or without d-c bias. The circuitry of the BOP consists of the following major sections:

A) BIPOLAR OUTPUT STAGE
B) GATE CIRCUIT
C) VOLTAGE CHANNEL
D) CURRENT CHANNEL
E) (±)10V REFERENCE SUPPLY
F) VOLTAGE LIMIT CIRCUIT
G) CURRENT LIMIT CIRCUIT

4-5 BIPOLAR OUTPUT STAGE. The bipolar power output stage consists of two groups of PNP/NPN power transistors (only one PNP and one NPN transistor is shown in FIG. 4-5. The actual number of PNP and NPN power transistors depends on the BOP model), two RAW D-C SUPPLIES, the QUIESCENT CURRENT CONTROL CIRCUIT and the three current sensing resistors (R_{SP}, R_{SC}, R_{SN})[1].

4-6 The QUIESCENT CURRENT CONTROL CIRCUIT has the function of keeping a constant current flowing through the power stage, regardless of the loading condition and/or the direction of the load current. This circuit is unique in that the circulating quiescent current is much less than in commonly used circuits of this kind, thus achieving superior efficiency. Under "no load" conditions, the quiescent current is controlled by the first feedback loop, including sensing resistors R_{SN} and R_{SP}, in series with the NPN/PNP power transistors. The no load quiescent current is sensed by the current resistors, the resulting voltage drops are compared and the difference voltage is amplified and used to drive both the NPN and PNP power stages, resulting in a constant current through both, PNP and NPN power transistors.

4-7 Under load conditions, the load current is monitored by the common sensing resistor (R_{SC}). A second feedback loop around R_{SC} is used to compensate in such a way, that the quiescent current is maintained, regardless of the magnitude and direction of the load current.

[1] The BOP 200-1M uses dual N-Channel FET power transistors with optically isolated driver circuits. The principle of operation however, remains the same.

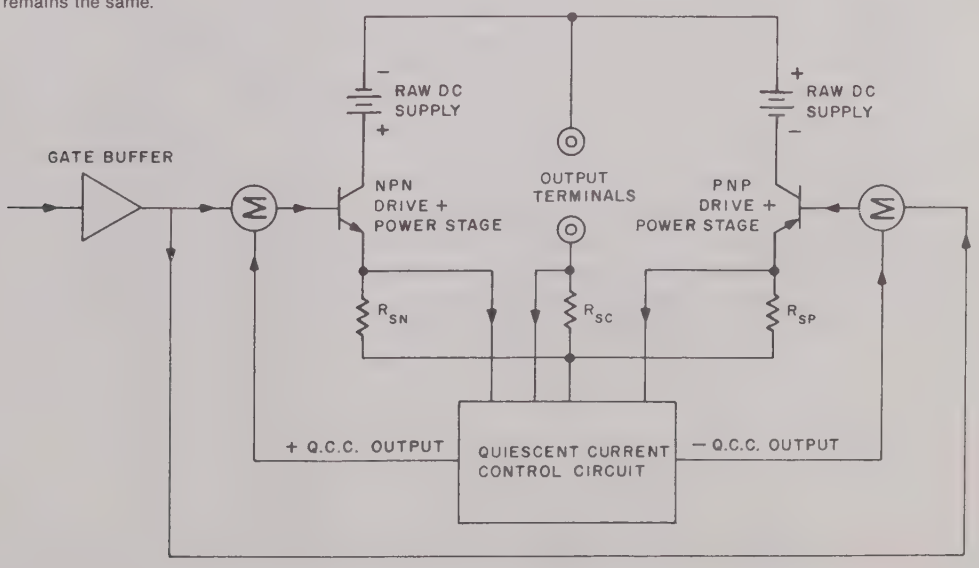


FIG. 4-1 NPN/PNP POWER STAGE WITH QUIESCENT CONTROL CIRCUIT

4-8 GATE CIRCUIT. The gate circuit operates as a multiple analog gate, permitting no more than a single amplifier to take control of the DRIVER and thereby the BOP output. All other amplifiers are normally biased "off". If, for example, the E_o COMP AMP is in control (BOP in VOLTAGE MODE) and an overcurrent condition occurs, the CURRENT SENSING AMPLIFIER develops a feedback signal of sufficient magnitude to overcome the back bias on the I_o LIMIT COMP AMP. Simultaneously, the feedback signal on the E_o COMP AMP is reduced (due to decreasing output voltage). As a result, the I_O LIMIT COMP AMP takes control of the NPN/PNP OUTPUT STAGE, transferring the BOP into the CURRENT LIMIT MODE of operation.

4-9 VOLTAGE CONTROL CHANNEL. With the MODE switch in the "VOLTAGE" position, the BOP d-c output voltage can be either controlled by connecting PREAMP "A" to the bipolar VOLTAGE CONTROL, or by connecting an external ± 10 volt (1 mA) signal to the VOLTAGE PROGRAMMING INPUT, or by summing the d-c bias with an external input signal. For input signals with an amplitude of less than 10 volts, the PREAMP "A" gain (unity with the built-in feedback and input resistors) can be altered to suit the available input signal. Signal sources not able to deliver 1 mA of signal current can be accommodated by using the (high impedance) non-inverting input of the PREAMP "A". The total gain of the BOP VOLTAGE CHANNEL is designed such that a (±) 10 volt drive signal, either via PREAMP "A" or directly applied to the E_o COMP AMP, will produce the rated BOP output voltage swing.

4-10 CURRENT CONTROL CHANNEL. With the MODE switch in the "CURRENT" position, the BOP d-c output current can be either controlled by connecting the PREAMP "B" to the BIPOLAR CURRENT control, or by connecting an external (±) 10 volt (1 mA) signal to the I_o COMP AMP, or by summing the d-c bias with an external input signal. For input signals with an amplitude of less than 10 volts, PREAMP "B" gain (unity with the built-in feedback and input resistors) can be altered to suit the available input signal. Signal sources not able to deliver 1 mA of signal current can be accommodated by using the (high impedance) non-inverting input of PREAMP "B". The total gain of the BOP current channel is designed such that a (±) 10 volt drive signal, either via PREAMP "B", or directly applied to the I_o COMP AMP, will produce the rated BOP output current swing.

4-11 ± 10V REFERENCE SUPPLY. The BOP dual d-c (± 10V) bias and reference voltage (shown as batteries on the Simplified Schematic Diagram, FIG. 4-5) are precision calibrated sources, derived from the stabilized amplifier power supply. The (±) 10 volt sources are available for external use on the REAR PROGRAMMING CONNECTOR with reference to COMMON. For internal biasing, they are connected to two 10-turn potentiometers (BIPOLAR control for VOLTAGE and CURRENT at the front panel). Connected via the "ON-OFF" switch to their respective control channel, the zero to (±) 10 volt d-c bias can control the BOP output voltage or current throughout its specified d-c output range.

4-12 VOLTAGE AND CURRENT LIMIT CIRCUITS. As seen from FIG. 4-5, the circuits for limiting the BOP output voltage and current are identical, except that the feedback for the voltage limit is taken from the (±) OUTPUT terminal, while the current limit feedback originates from the voltage drop across the current sensing resistor (R_{SC}). Both feedback signals are applied to the (+) input of their respective comparison amplifiers and dimensioned such that a zero to (±) 10 volt d-c signal to the (–) input of the comparison amplifier will control the voltage, as well as the current limit range. The control signal for internal control is derived from the (±) 10 volt reference sources and repeated by the $\pm E_o$ LIMIT AMPS or $\pm I_o$ LIMIT AMPS respectively. The control signals and therefore the $\pm E_o$ and $\pm I_o$ Limits are front panel adjustable. The control signal is applied directly to the (±) E_o and (±) I_o LIMIT COMP AMPS. The $\pm I_o$ and $\pm E_o$ control resistors are multi-turn controls, accessible from the BOP front panel, allowing manual adjustment of all limits ($\pm E_o$, $\pm I_o$) over the BOP output range. The limits can also be controlled externally, by means of a 0 to (+) 10 volt, 1 mA d-c signal. For simultaneous control of the (±)E_o or (±) I_o limit, the control voltage source is connected to the REAR PROGRAMMING CONNECTOR as shown in Section III, FIG. 3-24. For individual control of the (+) E_o or I_o and the (–) E_o or I_o limit, two control voltages (0 to (+)10V @ 1 mA) are required. They are connected as previously shown in Section III, FIG. 3-25.

4-13 THE MEANING OF THE PREAMPLIFIER OFFSET SPECIFICATIONS

4-14 The OUTPUT EFFECTS of the BOP as a d-c source of voltage or current, for variations in the various INFLUENCE QUANTITIES are tabulated in Section I (Table 1-2). These output effects are largely due to the preamplifier offsets and the variations in the reference potential, multiplied by the closed loop gain of the bipolar Voltage Channel (Voltage Mode) or that of the bipolar Current Channel (Current Mode). The published specifications are valid only for the *built-in values* of the preamplifier input/feedback resistors. If these values are altered by the user (as in remote programming) the BOP output effects must be calculated with the *new values* and the tabulated specifications for the PREAMPLIFIER OFFSETS (from Section I, Table 1-2). The expressions for the (worst case) BOP output effects are:

$$\text{(Voltage Mode)}\ \Delta E_o = G_V\,[\pm\Delta E_{io}\,(1 + R_f/R_i) \pm \Delta I_{io}\,(R_f)]$$

$$\text{(Current Mode)}\ \Delta I_o = G_I\,[\pm\Delta E_{io}\,(1 + R_f/R_i) \pm \Delta I_{io}\,(R_f)]$$

where: ΔE_{io} = Pre-amp Offset Voltage Variation (from Section I, Table 1-3).
ΔI_{io} = Pre-amp Offset Current Variation (from Section I, Table 1-3).
G_V = Closed Loop Gain, Voltage Mode (See Section I, Table 1-1).
G_I = Closed Loop Gain, Current Mode (See Section I, Table 1-1).
R_f = External Feedback Resistor Value.
R_i = External Input Resistor Value.

4-15 As a practical example, let us assume than on Model BOP 50-2M the PREAMP "A" gain has been changed from the original "one" to "ten". This would mean the input resistor value (10K) has been maintained and the feedback resistor (R_f) has changed from 10K to 100K. The BOP is used as a d-c voltage source and the output variations over a 10°C temperature change are to be calculated.

A) From Section I, Table 1-2; the PREAMPLIFIER OFFSETS are: $\Delta E_{io} = 20\ \mu V$, $\Delta I_{io} = 1$ nA. The input/feedback resistors are: $R_i = 10K$, $R_f = 100K$.

B) Inserting the offsets and the values of the feedback/input resistors into the given equation:
$\Delta E_o = 5[20\ \mu V\,(1 + 10) + 1\text{ nA}\,(100K\Omega)]$
$\Delta E_o = 5(220\ \mu V + 100\ \mu V)$
$\Delta E_o = 1.6$ mV per °C (maximum output voltage change)

C) For a temperature change of 10°C, therefore, a 16 mV change in output voltage is the maximum variation to be expected.

NOTE: *If the internal BIPOLAR BIAS (Reference) Voltage is used to produce the output voltage, its tabulated variation (0.0005% of 10 volts = 50 μV per °C) must be added to the calculated result. If an* ***external*** *voltage source is used to program the BOP,* ***its*** *variations with temperature must be added.*

4-16 BOP CIRCUIT DESCRIPTION (SEE MAIN SCHEMATIC, SECTION VI, FIG. 6-5)

4-17 GENERAL. This section contains a description of the major circuitry of the Kepco Bipolar Operational Power Supplies. The BOP consists of a MAIN CHASSIS ASSEMBLY (A2) with attached FRONT PANEL and contains a total of four (4) subassemblies (¾-Rack Units) or five (5) subassemblies (Full-Rack Units):

1) MAIN CHASSIS ASSEMBLY WITH FRONT PANEL	(A2), Component Numbers 101—109 and 201—299
2) CONTROL CIRCUIT AND REFERENCE ASSEMBLY	(A1), Component Numbers 1—99
3) DRIVER ASSEMBLY	(A3), Component Numbers 301—399
4) HEATSINK ASSEMBLY	(A4), Component Numbers 401—499
5) HEATSINK ASSEMBLY	(A5), Component Numbers 501—599

4-18 The subassemblies and the main chassis assembly are identified in the Disassembly drawing, Section V, FIG. 5-1. Subassemblies may be individually removed from the main chassis assembly by following the directions given in the drawing. Any component identified on the Main Schematic Diagram (Section VI, FIG. 6-4) may be traced to its physical location on the subassembly by means of its reference designations, the Disassembly drawing (Section V, FIG. 5-1) and the assembly listing in paragraph 4-17.

4-19 **A-C INPUT CIRCUIT.** A-C source power is introduced via the three-wire line cord which connects to the A-C POWER INPUT connector (P201). The center contact of P201 is connected to the BOP metal chassis. If the supplied, three-wire line cord with safety plug is used to connect the BOP to a properly grounded power outlet, safety (a-c) grounding is automatically accomplished.

4-20 Once the A-C CIRCUIT BREAKER/POWER SWITCH (CB101) is placed in the "on" position, the primary windings of the main transformer (T201) and the auxiliary transformer (T202) are energized together with the fan (B201, single fan; or B201, B202 dual fans, depending on BOP model). The tapped primary windings on the main transformer (T201) are series or parallel connected for a variety of a-c input source voltages by means of the link connections on the transformer barrier strip. The A-C CIRCUIT BREAKER/POWER SWITCH (CB101) protects the BOP from overloads reflected into the primary of T201 and shuts off automatically if the turn-off crowbar circuit is activated. The sensing coils on CB101 are wired into the a-c input circuit in such a way that equal protection is provided for any a-c source voltage.

4-21 **MAIN D-C SUPPLY.** The dual MAIN D-C SUPPLY is derived from the center tapped secondary winding on the main transformer (T201). Rectified by a bridge rectifier (CR201) and capacitor filtered (C201,C202), the raw d-c voltages are applied to the NPN/PNP POWER STAGE as shown in FIG. 4-2. The MAIN D-C SUPPLY delivers the output current of the BOP via the series connected NPN/PNP POWER STAGE. All filter capacitors are paralleled by bleeder resistors (R201,R202).

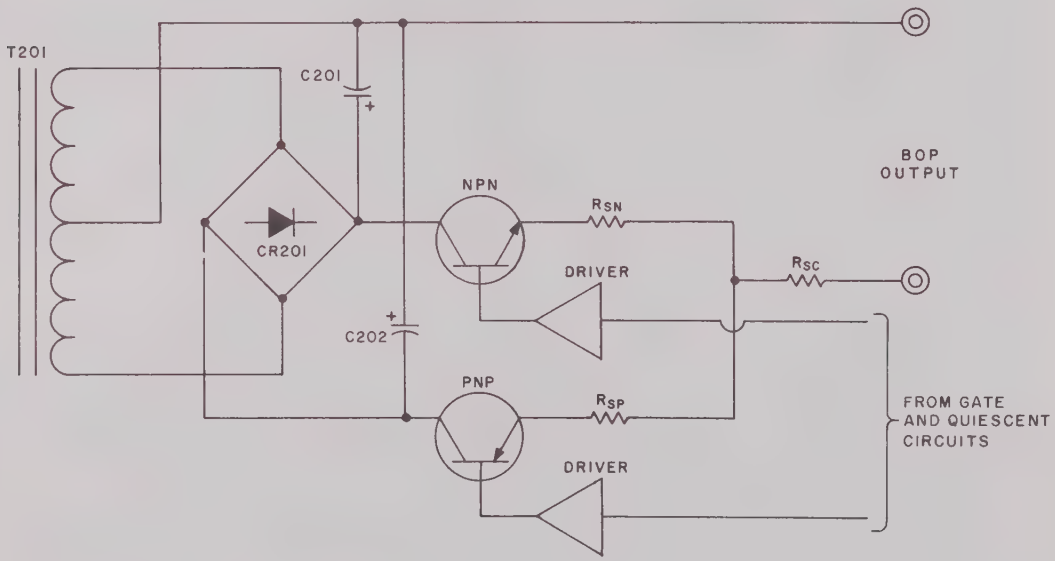


FIG. 4-2 MAIN D-C SUPPLY AND NPN/PNP POWER STAGE WITH DRIVERS.

NOTE: *Model BOP 200-1M uses dual N-Channel FET power transistors with optically isolated driver circuits. The principle of operation, however, remains the same.*

4-22 **OUTPUT POWER STAGE.** The output power stage, shown in FIG. 4-2 as two single complementary transistors, consists in reality of two groups of SERIES/PARALLEL connected NPN/PNP power transistors. The number of NPN/PNP power transistors will depend on the individual BOP model. These power transistors are mounted on a single common heatsink (A4) on ¾ Rack BOP models cooled by a single fan (B201) and on two heatsinks (A4,A5) on Full Rack BOP models, cooled by two fans (B201,B202)

4-23 **DRIVER STAGE.** The output power stage is driven by PNP/NPN power transistors, mounted with their base series resistors onto a common heat sink (A3). The number of PNP/NPN driver transistors (Q301) is dependent on the model, with an increasing number of NPN and PNP transistors for BOP models with larger output voltage ratings.

4-24 THE REFERENCE AND AUXILIARY POWER SUPPLIES. All auxiliary d-c sources are derived from secondary windings on the auxiliary transformer (T201).

A) The DRIVER COLLECTOR SUPPLY is a dual d-c source with a bridge rectifier (CR1) and capacitor filters (C1,C5). It provides the (±) collector voltages for the power transistors in the DRIVER ASSEMBLY (A3).

B) The (±)15 VOLT SUPPLY is a dual d-c source with a bridge rectifier (CR2) and a capacitor filter (C2,C3). It provides the (±) operating potential for the linear intergrated circuits (IC-4 thru IC-15 and IC-18 thru IC-23 or IC24[1]). The rectified and filtered (±) voltages are stabilized by the three-pin regulators (IC-1 for the +15 volt side, IC-2 for the −15 volt side) and capacitor filtered (C7,C8).

C) The (±)12 VOLT SUPPLY is a dual d-c source derived by means of zener diodes (CR6 for the +12 volt side, CR7 for the −12 volt side) with their associated series resistors (R10,R14). The (±)12 volt supply serves as a terminating bus for the protective signal diodes, connected to the input of the preamplifiers (IC-5, IC-6), the I_Q SENSING AMP (½ IC-18), the I_o SENSING AMP (IC-20), the E_o COMPARISON AMP (IC-10) and the I_o COMPARISON AMP (IC-11). By terminating the protective diodes in this fashion, the common mode voltage limit on these amplifiers is increased to greater than 10 volts.

D) The (±)10 VOLT REFERENCE SUPPLY is a dual d-c source derived from the stabilized (±)15 VOLT SUPPLY. The positive 10 volt supply uses an operational amplifier (½ IC-4) in the non-inverting configuration to create the (+) 10 volt output, via the series pass transistor (Q3) from the reference voltage zener (CR8). Part of the feedback resistance (R29,R31) is adjustable for calibration of the (+)10 volt reference source (+10V CAL, R31). The negative 10 volt supply uses the (+)10 volt source as reference source. An operational amplifier, ½IC-4) in the inverting configuration, has its input resistance (R26,R32) partially adjustable for calibration of the (−)10 volt reference source (−10V CAL, R32), while its feedback resistance (R22) is fixed. The (±)10 volt reference supply is used to provide the internal reference voltages for front panel (local) control of the output voltage, output current, as well as the voltage and current limit of the BOP.

E) The 5 VOLT SUPPLY is a positive voltage supply, referenced to the COMMON. Derived from a bridge rectifier (CR3) and filtered by C4, the supply is stabilized by a three-pin regulator (IC-3) and again filtered by a capacitor (C9). The 5 volt supply provides the operating voltages for the digital IC's (IC-15, IC-16, IC-17), which are used for the LOCAL/REMOTE I_o/E_o CIRCUIT (IC-15) and which operate as drivers for the LED front panel indicators (E_o LIMIT—DS101, I_o LIMIT—DS102, E_o MODE—DS103 and I_o MODE—DS104). The 5 volt supply also provides the operating voltages for the CIRCUIT BREAKER CONTROL CIRCUIT (Q1, Q2, LC-1, LC-2, CR4).

4-25 THE CIRCUIT BREAKER CONTROL CIRCUIT (REFER TO FIG. 4-3). The BOP is protected by the dual-coil CIRCUIT BREAKER/ON-OFF SWITCH (CB101). The current sensing coil of CB101 is connected in series with the primary winding of T201, thus detecting overcurrents reflected into the primary circuit and subsequently tripping the circuit breaker. The voltage sensing coil of CB101 is connected in series with an SCR (CR4) across the DRIVER COLLECTOR SUPPLY. If the SCR is triggered "on", the voltage sensing coil is energized and trips the circuit breaker. The SCR (CR4) can be triggered in several ways as described in paragraphs 4-25A thru 4-25D.

Since the Model BOP 200-1M uses dual N-Channel FET power transistors, optically isolated separate driver circuits with separate DRIVER COLLECTOR SUPPLIES and two transistors (Q301, Q302) are used to short the collector supplies (See Main Schematic Diagram, Section VI, FIG. 6-4). The principle of operation of the CIRCUIT BREAKER CONTROL CIRCUIT, however remains the same.

[1] IC 24 is used only in Model BOP 200-1M.

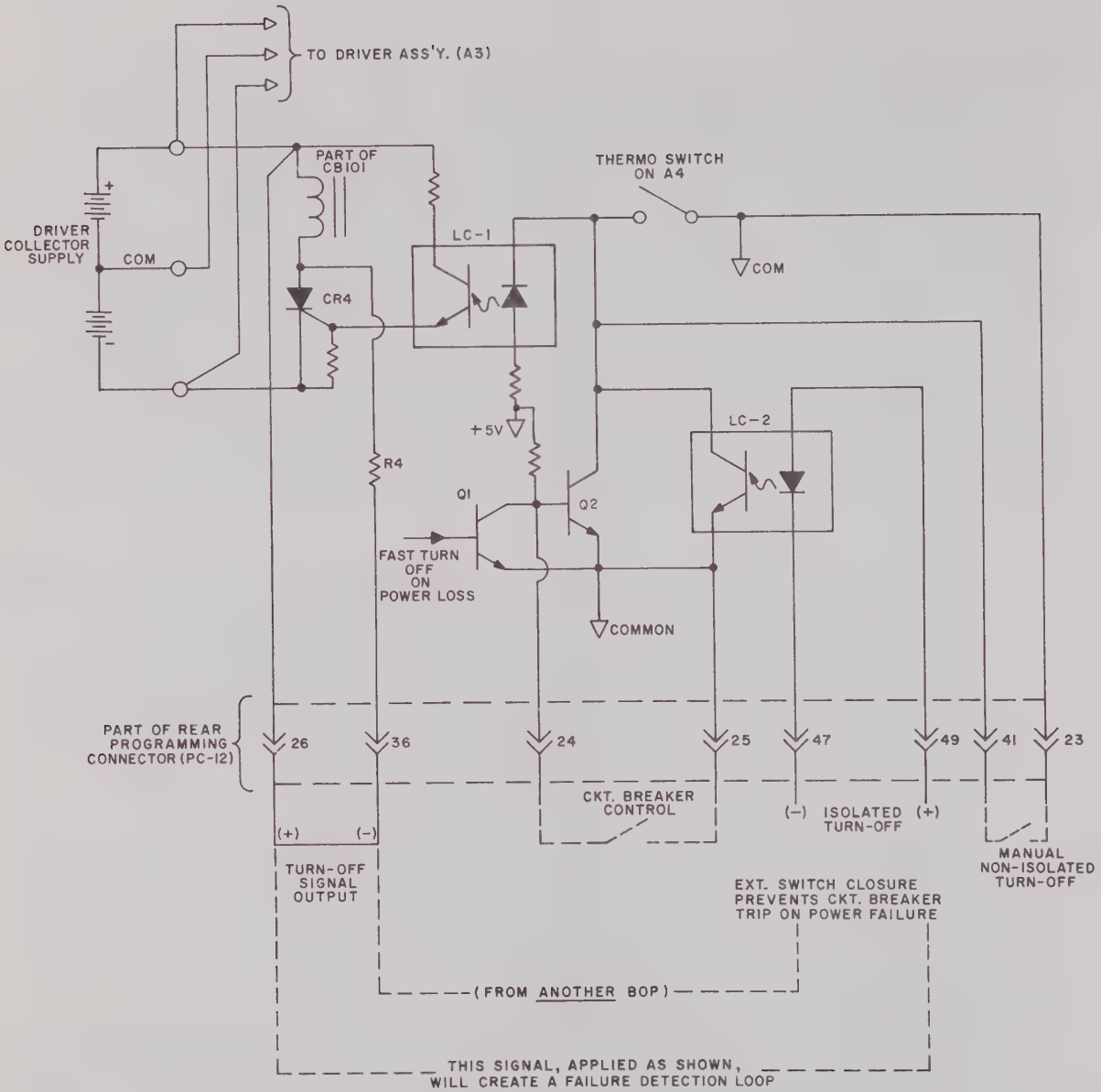


FIG. 4-3 CIRCUIT BREAKER CONTROL CIRCUIT, SIMPLIFIED DIAGRAM.

A) On a-c line power loss or interruption, Q1 will loose its turn-on bias first, due to the small time-constant provided in its base circuit (R2, R3, C4 see Main Schematic Diagram). As a result, Q2 is turned "on", energizing the diode in the optical isolator (LC-1) and providing a turn-on signal for the SCR (CR4).

B) In the event of an excessive heat rise on the POWER STAGE ASS'Y (A4), the thermal switch (S401) will close, energizing the diode in the optical isolator (LC-1) and providing thus the turn-on signal for the SCR (CR4).

C) In the event of an external, isolated turn-off signal (which, for example, in system applications, could originate from a companion BOP), the diode in the second optical isolator (LC-2) is energized. The resulting signal energizes in from the diode in the first optical isolator (LC-1) thus providing for SCR turn-on.

D) A manual, non-isolated turn-off is provided which, when implemented with an external switch contact as shown in FIG. 4-3, will energize the diode in the first opto coupler (LC-1), thus providing the SCR turn-on.

4-26 If it is not desired to trip the circuit breaker (CB101) on a-c line power loss, it can be prevented by a jumper wire or an external switch across Pins 24 and 25 on PC-12. In this manner, Q1 is inhibited from providing a turn-on signal for Q2, thus avoiding triggering the SCR and tripping the circuit breaker.

4-27 **THE VOLTAGE AND CURRENT CONTROL CHANNELS.** These control channels are electrically identical, except for component reference designations, the terminations on the rear programming connector and the manner in which their feedback is derived. Only the voltage channel will be described here. THE VOLTAGE CONTROL CHANNEL consists of PREAMP "A" (IC-5) and the E_o COMPARISON AMPLIFIER (IC-10) with their associated components. The preamp inputs and outputs are terminated on the rear programming connector (PC-12) and the output is linked via PC-12 to the E_o COMP AMP (IC-10). In the local (front panel) control mode, with the MODE switch (S102) in the VOLTAGE position, the PREAMP "A" is committed as an inverter (GAIN = −1). Bipolar output voltage control can be exercised by closing the VOLTAGE CONTROL switch (S101). Now the VOLTAGE CONTROL potentiometer, (R105) is connected across the (±)10 volt INTERNAL REFERENCE SOURCE. The 0 to (±)10 volt control voltage is applied, via PREAMP "A" (GAIN = −1) to the E_o COMP AMP (IC-10), and compared with the voltage feedback signal (via RN2 resistor divider). The E_o COMP AMP takes control of the GATE and DRIVER circuits and varies the BOP output voltage over the rated range.

4-28 In an external mode, the internal VOLTAGE CONTROL can be disconnected via S101 and the PREAMP may be connected for other closed loop gain configurations to accommodate various input sources. The BOP may also be controlled over its rated output voltage range by a (±)10 volt external control source, applied directly to the E_o COMP AMP input via the rear programming connector (PC-12). Some of the external control modes have been described previously, see Section III of this manual.

4-29 **THE VOLTAGE AND CURRENT LIMIT CIRCUITS.** The (±) E_o and (±) I_o LIMIT CIRCUITS are electrically identical except for component reference designations, the origin of the feedback signals and the terminations on the rear programming connector (PC-12). Only the voltage limit circuit (± E_o LIMIT) will be described here. The (±) E_o limit circuit consists of the (±) E_o LIMIT AMPS/EXT (½ IC-7) the (±) E_o LIMIT AMPS/INT (½ IC-7) and of the (±) E_o LIMIT COMPARISON AMPLIFIERS (E_o LIMIT AMPS-½ IC-9). In the local (front panel) control mode the ± voltage limit points can be manually set by means of the front panel (±) E_o LIMIT controls (R103, R104). These controls are connected across the ±10 volt reference source, so that a ±10 volt control signal is applied to the (±) E_o LIMIT AMPS/INT (½ IC-7), which are connected as voltage followers, and control the (±) E_o COMP AMP's (½ IC-9). The voltage feedback to the (±) E_o COMP AMPS is applied via R17 and is dimensioned for each BOP model so that a ± 0–10 volt control signal will control the voltage limit points over the rated output voltage range.

4-30 **THE INDICATOR AND FLAG LOGIC CIRCUIT (SEE FIG. 4-4).** Digital logic circuits (IC-15, IC-16, IC-17) are used in the BOP to drive the LED front panel lamps which indicate the prevailing operating mode:

E_o LIMIT MODE	(DS101)
I_o LIMIT MODE	(DS102)
E_o MODE	(DS103)
I_o MODE	(DS104)
REMOTE	(DS105)

Together with these visual front panel indicators, TTL-compatible status flags are provided at the rear programming connector (PC-12) for the above BOP operating modes. All status flags available on PC-12 indicate a logic "0" if the BOP is operating in the indicated operating mode, and a logic "1" if it is not.

4-31 The logic status indicated in FIG. 4-4 are valid for the BOP operating in the voltage mode (E_o MODE) and not driven by the GPIB INTERFACE. If the GPIB interface is connected, control of the BOP output may be assumed by the external controller, once the "REMOTE" command is applied via J204/P5 Pin 6. At this time, the REMOTE/LOCAL FLAG (PC-12 pin 35) will go to "0", the REMOTE front panel lamp goes on and the front panel MODE SWITCH (S103) is no longer functional. All other front panel LED indicators will function as in the local control mode.

4-32 **METERING CIRCUITS.** The output voltage meter (M102) is a center-zero reading device and measures the (±) BOP output voltage directly across the error sensing terminals. The output current meter (M101) is also a center-zero reading device and is driven by the I_o SENSING AMP (IC-20) which has a zeroing adjustment (R50 "AMMETER ZERO"). Both meters will read the d-c output (or average a-c output).

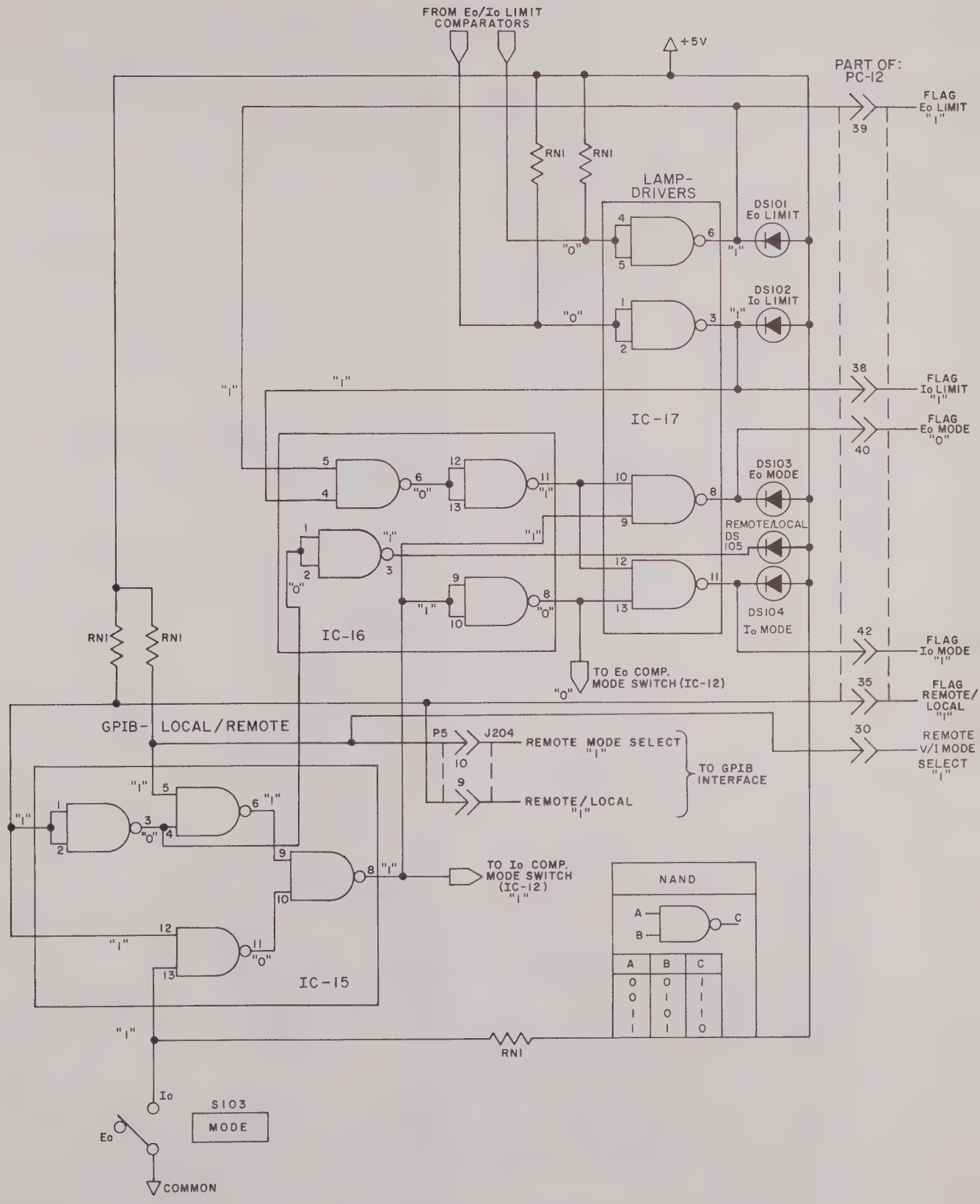
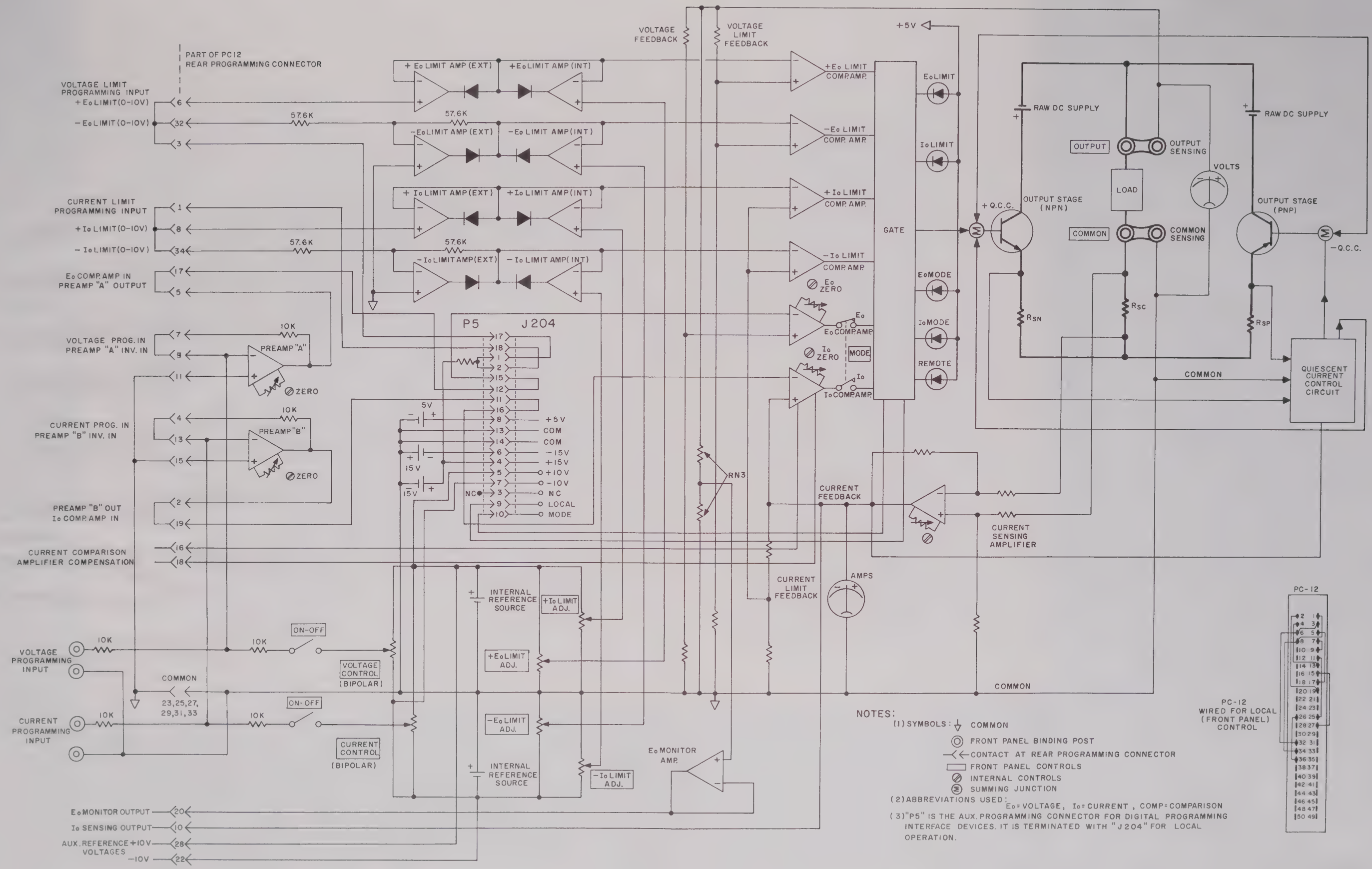


FIG. 4-4 INDICATOR LIGHT AND FLAG LOGIC.
CONDITIONS SHOWN: Eo MODE, GPIB "LOCAL".

4-9/4-10

BOP—05-0186



NOTES:

(1) SYMBOLS: ⏚ COMMON
◎ FRONT PANEL BINDING POST
—|← CONTACT AT REAR PROGRAMMING CONNECTOR
▭ FRONT PANEL CONTROLS
⊘ INTERNAL CONTROLS
Σ SUMMING JUNCTION

(2) ABBREVIATIONS USED: Eo = VOLTAGE, Io = CURRENT, COMP = COMPARISON

(3) "P5" IS THE AUX. PROGRAMMING CONNECTOR FOR DIGITAL PROGRAMMING INTERFACE DEVICES. IT IS TERMINATED WITH "J204" FOR LOCAL OPERATION.

BOP—05-0186

FIG. 4-5 SIMPLIFIED SCHEMATIC DIAGRAM, BOP SERIES.

SECTION V—MAINTENANCE

5-1 GENERAL

5-2 This section covers maintenance and those calibration procedures for the BOP Operational Power Supply/Amplifier which were not covered previously in this manual. Conservative ratings of components and non-congested layout should keep maintenance to a minimum. If trouble does develop, however, the easily removed wrap-around cover in conjunction with the plug-in feature of all major component boards provide exceptional accessibility of the circuitry.

5-3 DISASSEMBLY

5-4 Remove the wrap-around cover and disassemble the printed circuit board card and assemblies as described and illustrated in FIG. 5-1 below.

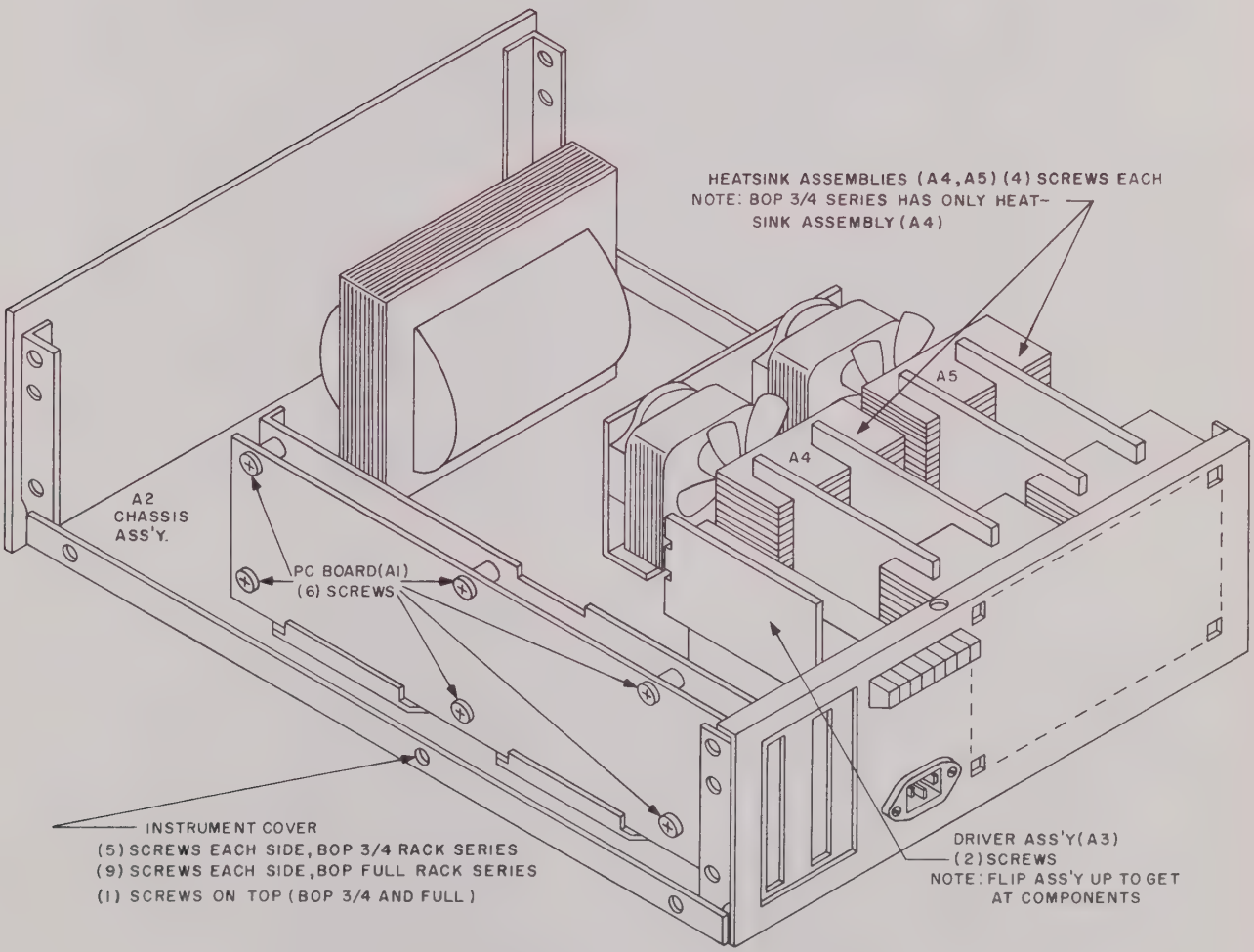

HEATSINK ASSEMBLIES (A4,A5) (4) SCREWS EACH
NOTE: BOP 3/4 SERIES HAS ONLY HEAT-SINK ASSEMBLY (A4)
A5
A4
A2 CHASSIS ASS'Y.
PC BOARD(A1) (6) SCREWS
INSTRUMENT COVER
(5) SCREWS EACH SIDE, BOP 3/4 RACK SERIES
(9) SCREWS EACH SIDE, BOP FULL RACK SERIES
(1) SCREWS ON TOP (BOP 3/4 AND FULL)
DRIVER ASS'Y (A3)
(2) SCREWS
NOTE: FLIP ASS'Y UP TO GET AT COMPONENTS

FIG. 5-1 DISASSEMBLY, BOP SERIES.

NOTE: *BOP FULL-RACK MODEL SHOWN, FOR ¾ RACK BOP MODELS, SEE SPECIAL REFERENCES IN DISASSEMBLY NOTES ON FIG. 5-1.*

5-5 PERIODIC MAINTENANCE

5-6 The inside of the BOP should be periodically cleaned of dust and grime to ensure continued cooling efficiency. In normal laboratory environments, the recommended maintenance interval is six (6) months.

5-7 INTERNAL ADJUSTMENTS AND CALIBRATIONS

5-8 The location of all internal controls is illustrated in Section II, FIG. 2-1. The use of the zeroing controls for the BOP output voltage and current has been described in Section III. The adjustment for the remaining controls is described below:

Note: *These controls are factory calibrated. Re-calibration is necessary only if components, related to the circuitry involving these controls have to be replaced.*

A) ADJUSTMENT OF THE (±) 10 VOLT CALIBRATION CONTROLS (R31,32)

1) Connect a precision digital voltmeter to the REAR PROGRAMMING CONNECTOR (PC-12) from COMMON to pin 22 (– 10 volt) and subsequently to pin 28 (+ 10 volt).
2) Turn the BOP "on" and locate the calibrating controls (see Section II, FIG. 2-1).
3) Adjust control to exactly 10 volts as read out on the digital voltmeter.

B) ADJUSTMENT OF THE AMMETER ZERO CONTROL (R50)

1) Without a load connected to the BOP output, connect a digital voltmeter to the REAR PROGRAMMING CONNECTOR (PC-12) from COMMON to pin 10.
2) Turn the BOP "on" and locate the AMMETER ZERO control (R50, see Section II, FIG. 2-1).
3) Adjust control to exactly zero volts as read out on the digital voltmeter.

C) ADJUSTMENT OF OPTOCOUPLER LINEARIZATION CONTROL (ONLY IN MODEL BOP 200-1M).

1) Remove the BOP cover.
2) Connect a resistive load to the output. Set load to produce the rated maximum output current.
3) Attach an oscilloscope probe to test point, located on A1 control board (See Section VI, FIG. 6-1). (Oscilloscope common should be connected to output common of the unit). Select 1V/Division or 2V/Division sensitivity on the oscilloscope.
4) Set BOP to Voltage Mode with voltage control switch on "off" position (See Section II, FIG. 2-2).
5) Using the Voltage Programming Input terminals, program the unit by using a triangular voltage source (Function Generator) producing a 20V p-p, 250 Hz triangular wave. Observe the output signal on the scope, and adjust R15A Linearization control (See Section II, FIG. 2-1) until the non-linearity in the ramps of the triangular wave disappears (See FIG. 5-2).

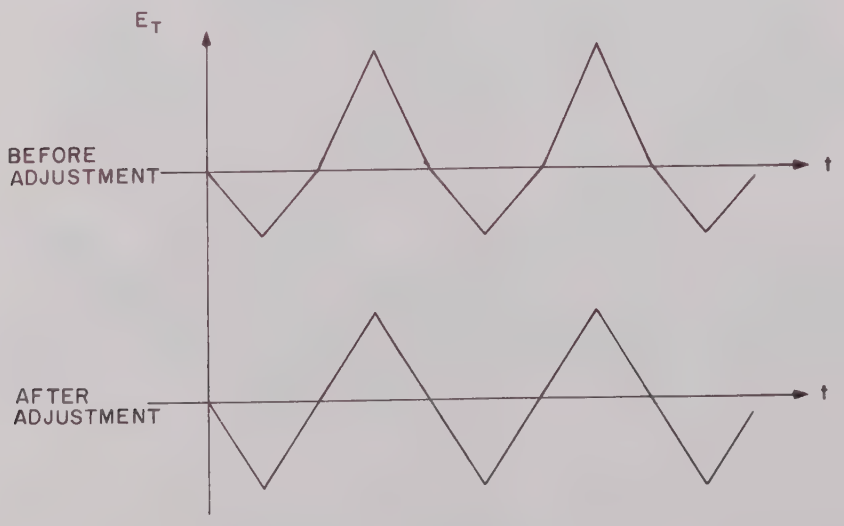


FIG. 5-2 OPTOCOUPLER LINEARIZATION IN MODEL BOP 200-1M.
*(**NOTE:** THE TRIANGULAR WAVE DOES NOT HAVE TO SHOW ZERO VOLT D-C AVERAGE).*

5-9 TROUBLE SHOOTING

5-10 Trouble analysis of precision power supplies containing operational amplifiers requires a thorough understanding of the operational concept, experience with solid-state circuitry and appreciation of the problems encountered in closed-loop systems. Repair beyond simple part replacement and recalibration should therefore be handled only by personnel familiar with those concepts. "Trouble Shooting Charts" giving resistance and voltage ratings at various parts in the circuitry are of little value in feedback amplifiers and for this reason are not included here.

Instead, a systematic approach to trouble analysis is presented. Follow the flow diagram (FIG. 5-3) and refer to the applicable paragraphs. For further help in circuit analysis, refer to Section IV (Operational Theory and Circuit Description) and to the Main Schematic Diagram, Section VI (Fig. 6-5). For the actual repair and replacement of components refer to the Disassembly Diagram FIG. 5-1, the Parts Location Diagram, the Connection Diagram and the Replacement Parts List, in Section VI of this manual.

NOTE: *KEPCO FIELD ENGINEERING OFFICES, AND THE KEPCO REPAIR AND APPLICATIONS ENGINEERING DEPARTMENTS, ARE ALWAYS AVAILABLE FOR PROMPT SERVICE IN DIFFICULT REPAIR OR APPLICATION CASES.*

5-11 TROUBLE ANALYSIS

NOTE: The POWER STAGE consists of one heatsink assembly (A4) in BOP ¾ Rack models and of two heatsink assemblies (A4, A5) in BOP Full Rack models.

STEP NO. 1: Disconnect BOP from the a-c input source, from the load and from all auxiliary sources such as input signal generators, etc.

STEP NO. 2: Restore ALL jumper links on the rear barrier-strip and on the REAR PROGRAMMING CONNECTOR PC-12 to those for Standard Power Supply operation (see Section IV, FIG. 4-5).

STEP NO. 3: Perform the PRELIMINARY ELECTRICAL CHECK, as described in Section II of this manual. **If the BOP functions as described** in this operating mode, the trouble or malfunction must be traced to external causes or interface problems. Check all interconnecting wires between the input sources and the BOP, and all load and error-sensing wiring between the BOP and the load. **If the BOP does not function** in the standard power supply mode, proceed to Step No. 4.

STEP NO. 4: Follow the FLOW CHART (FIG. 5-3) and refer to the appropriate paragraphs.

5-12 DISCONNECT BOP FROM THE A-C POWER SOURCE and:

A) Check if the BOP is set to the correct a-c input voltage. (See Section II, paragraph 2-4).

B) Check if the thermo-switch (S401) in the POWER STAGE (A4) is open. Replace if defective. Check S501 in A5 if used. If it is not, check the power stage as described in paragraph 5-13B.

5-13 Check LED lamp DS103 and replace if defective.

A) If there is no output voltage, check if the d-c control voltage reaches the E_o COMP AMP input by placing a voltmeter from COMMON to pins 5,17 on the REAR PROGRAMMING CONNECTOR (PC-12). The voltage read-out should be from (−)10 volt, over zero, to (+)10 volt, as the front panel VOLTAGE CONTROL is turned from its maximum counterclockwise to its maximum clockwise position. If the control voltage is not as described, check the nominal voltages on the CONTROL ASSEMBLY (A1) as indicated on the MAIN SCHEMATIC DIAGRAM. Check for burned components. Check IC-1,2,3, zener diodes, CR6,7, PREAMP "A" (IC-5). Replace defective components.

B) If the output voltage is high (either positive or negative) and not controllable by the front panel voltage control, check the DRIVER STAGE (A3) and the POWER STAGE as follows:

1) FOR HIGH NEGATIVE OUTPUT: Remove Q301 from its socket. Output should now be zero. Replace Q301. If output is still high, investigate the other NPN drivers (if applicable) by replacing them with known functioning units. Check the POWER STAGE for shorted NPN power transistors. Replace defective units.

2) FOR POSITIVE HIGH OUTPUT: Remove Q302 from its socket. Output voltage should now be zero. Replace Q302. If output is still high, investigate the other PNP drivers (if applicable) by replacing them with known functioning units. Check the POWER STAGE for shorted PNP power transistors. Replace defective units.

C) If the I_o LIMIT LED light is on, and the POWER STAGE is functioning, remove IC-9 from its socket. Replace if defective. ***NOTE:*** *Make certain when reinserting* ***any*** *IC, that pin 1 of the IC is oriented toward the marker placed near each IC socket on the CONTROL ASSEMBLY (A1) printed circuit board.*

5-14 Check LED lamp DS104 and replace if defective.

A) If there is no output current, check if the d-c control voltage reaches the I_o COMP AMP input by placing a voltmeter from COMMON to pins 2,19 on the REAR PROGRAMMING CONNECTOR (PC-12). The voltage read-out should be from (−)10 volt, over zero, to (+)10 volt, as the front panel CURRENT CONTROL is turned from its maximum counterclockwise to its maximum clockwise position. If the control voltage is not as described, check the nominal voltages on the CONTROL ASSEMBLY (A1) as indicated on the MAIN SCHEMATIC DIAGRAM. Check for burned components. Check IC-1,2,3, zener diodes CR6,7, PREAMP "B" (IC-6). Replace defective components.

B) If the output current is high (either positive or negative) and not controllable by the front panel CURRENT CONTROL, check the DRIVER STAGE (A3) and the POWER STAGE as follows.

1) FOR HIGH NEGATIVE OUTPUT: Remove Q301 from its socket. Output should now be zero. Replace Q301. If output is still high, investigate the other NPN drivers (if applicable) by replacing them with known functioning units. Check the POWER STAGE for shorted NPN power transistors.

2) FOR POSITIVE HIGH OUTPUT: Remove Q302 from its socket. Output should now be zero. Replace Q302. If output is still high, investigate the other PNP drivers (if applicable) by replacing them with known functioning units. Check the POWER STAGE for shorted PNP power transistors. Replace defective units.

C) If the E_o LIMIT LED light is on, and the POWER STAGE is functioning, remove IC-9 from its socket. Replace if defective. ***NOTE:*** *Make certain when reinserting* ***any*** *IC, that pin 1 of the IC is oriented toward the marker placed near each IC socket on the CONTROL ASSEMBLY (A1) printed circuit board.*

5-15 If the BOP functions correctly after the load has been removed (Voltage Mode), or after a short circuit has been placed across the output terminals (Current Mode), investigate your load condition:

NOTE: *For VOLTAGE MODE operation, your minimum load resistance ($R_{L\ MIN}$) is given by:*

$$R_{L\ (MIN)}\ (K\Omega) = \frac{\text{OUTPUT VOLTAGE SETTING (VOLTS)}}{\text{CURRENT LIMIT SETTING (mA)}}$$

Any load resistance SMALLER than $R_{L\ (MIN)}$ will transfer the BOP into the CURRENT LIMIT MODE (Current Limit Light "on").

NOTE: *For CURRENT MODE operation, your maximum load resistance ($R_{L\ MAX}$) is given by:*

$$R_{L\ (MAX)}\ (K\Omega) = \frac{\text{VOLTAGE LIMIT SETTING (VOLTS)}}{\text{OUTPUT CURRENT SETTING (mA)}}$$

Any load resistance GREATER than $R_{L\ (MAX)}$ will transfer the BOP into the VOLTAGE LIMIT MODE (Voltage Limit Light "on").

5-16 OPERATIONAL POWER SUPPLY PERFORMANCE MEASUREMENTS

5-17 GENERAL. Measurements to verify the performance specifications are a frequent requirement of **"Incoming Inspection"** departments, as a part of a routine maintenance program or as a part of repair procedures. Some operational power supply measurements (OUTPUT IMPEDANCE, DRIFT, TEMPERATURE COEFFICIENT, etc.) require specialized test equipment and /or a controlled environment, and are therefore not described here. For information on these measurements, consult the Kepco Engineering Test Department. The measurements described in the following paragraphs, require only a minimum of equipment, and are generally sufficient to verify the most important d-c and dynamic performance specifications.

5-18 REQUIRED INSTRUMENTATION

A) STABILIZED A-C INPUT SOURCE, with provisions for "stepping" the voltage over the specified a-c input range (105 to 125V or 210 to 250V). A variable AUTO-TRANSFORMER is generally adequate if it can deliver the required a-c input current.

B) RESISTOR LOAD, variable, capable of dissipating the full d-c output power of the unit under test and equipped with "on-off" and "shorting" switch (S1).

C) D-C VOLTAGE MONITOR, digital or differential voltmeter with a suitable voltage range for the model under test and able to resolve at least 1 microvolt (M1).

D) OSCILLOSCOPE, vertical sensitivity at least 10 mV/cm and with a minimum bandwidth of 10 megahertz.

E) SQUARE-WAVE GENERATOR, with a variable output amplitude of 0-10 volts into 600 ohms and rise time of at least 0.1 microseconds. A "floating output", where the signal is available either in positive or in the negative direction is desirable.

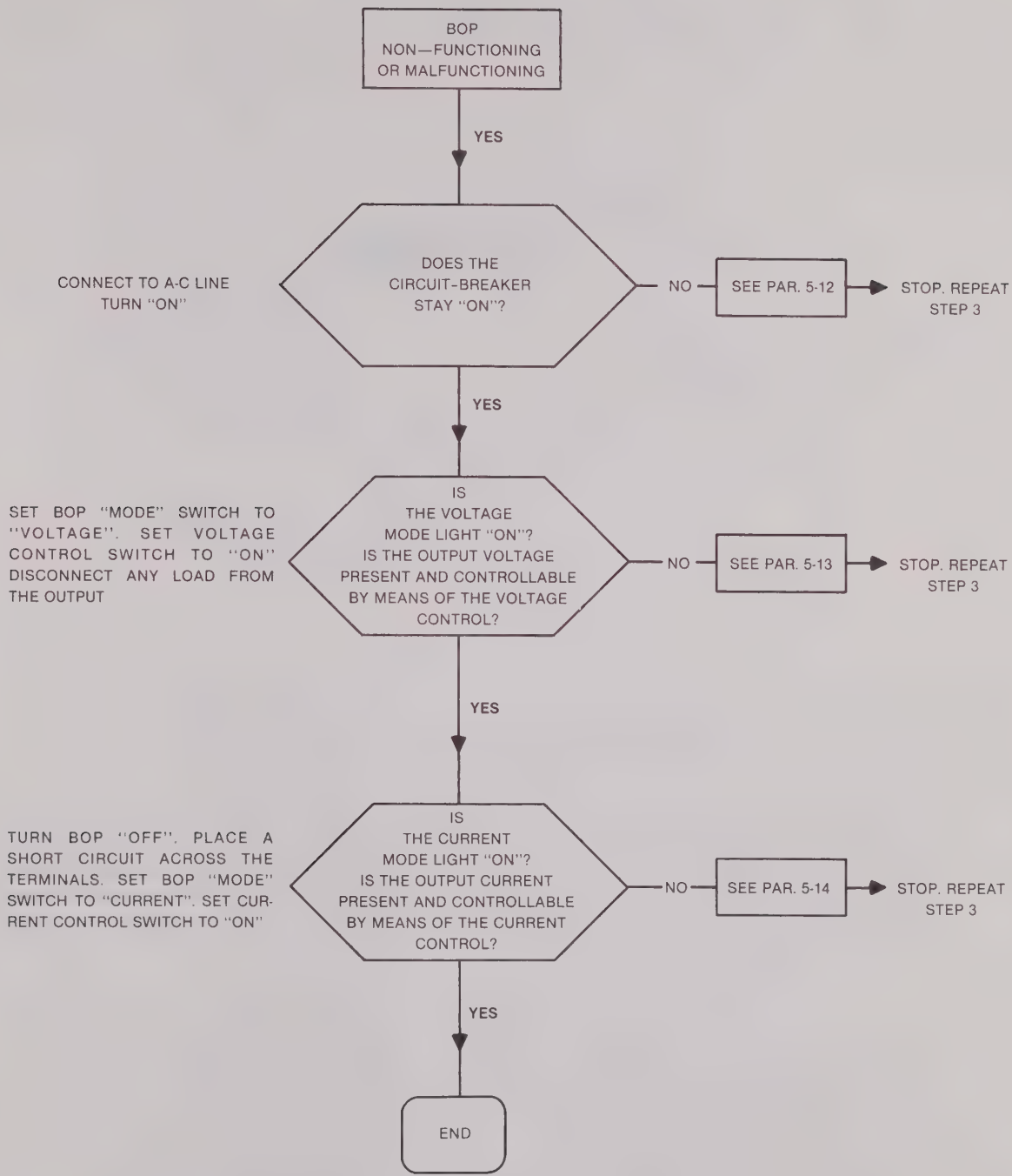


FIG. 5-3 TROUBLE SHOOTING, FLOW DIAGRAM

Notes:
1) Front and rear sensing links must be removed.
2) PC-12, wired for local (front panel) control must be connected (see Sect. IV, FIG. 4-5).
3) Mode Switch position: "VOLTAGE".

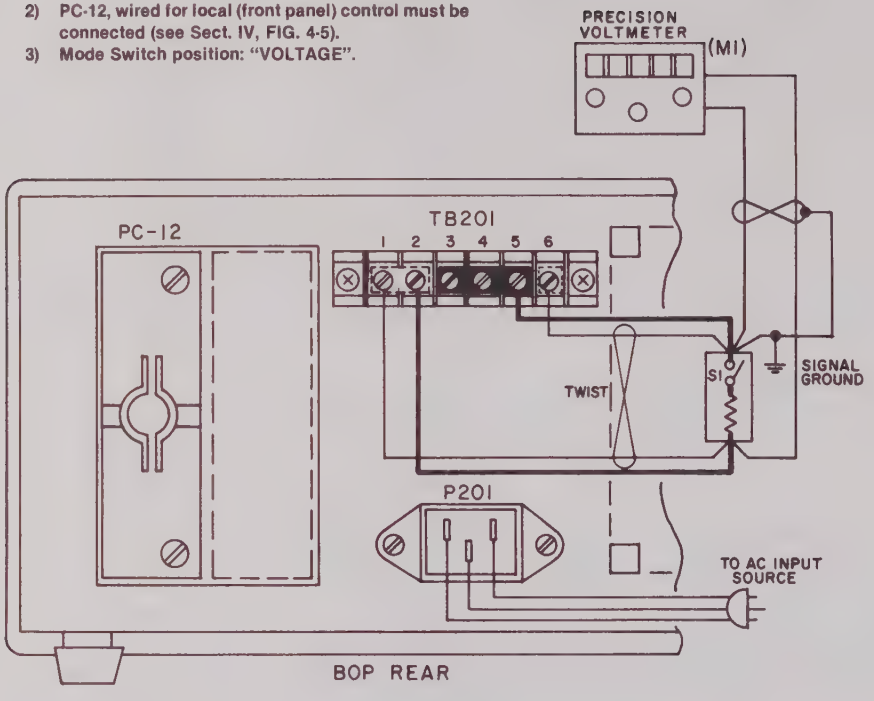


FIG. 5-4 OUTPUT EFFECT MEASUREMENTS, VOLTAGE CONTROL CHANNEL (TEST CIRCUIT).

5-19 **OUTPUT EFFECT MEASUREMENTS, VOLTAGE CONTROL CHANNEL.** The output effects due to load or a-c input source changes in the voltage mode can be measured with the circuit shown in FIG. 5-4. These output effects ("SOURCE EFFECT" and "LOAD EFFECT") are defined as the amount of output voltage change resulting from specified variations in the a-c source voltage, or from a change in load resistance (see Section I, Table 1-2). The output effects can be expressed as an absolute change (ΔE_o) or as a percentage of the total output voltage (E_o):

$$\% \text{ OUTPUT EFFECT} = \frac{\Delta E_o}{E_o} \times 100\% \text{ (Eq. 5-1).}$$

(Source or Load Effect)

where: ΔE_o = Change in output voltage
E_o = Total output voltage

5-20 PROCEDURE (Refer to FIG. 5-4)

1) Connect the BOP to a metered a-c input source, such as described in Paragraph 5-18A.
2) To measure the SOURCE EFFECT, vary the a-c source voltage over the specified range (105 to 125V or 210 to 250V) and note the deviation (ΔE_o) on the PRECISION VOLTMETER (M1).
3) To measure the LOAD EFFECT, open and close the load switch (S1) and note the deviation (ΔE_o) on the PRECISION VOLTMETER (M1).
4) From the results of the two previous measurements, calculate the Source Effect and the Load Effect by means of equation (5-1).

Notes: 1) PC-12, wired for local (front panel) control (see Sect. IV, FIG. 4-5).
2) Mode Switch position: "VOLTAGE".

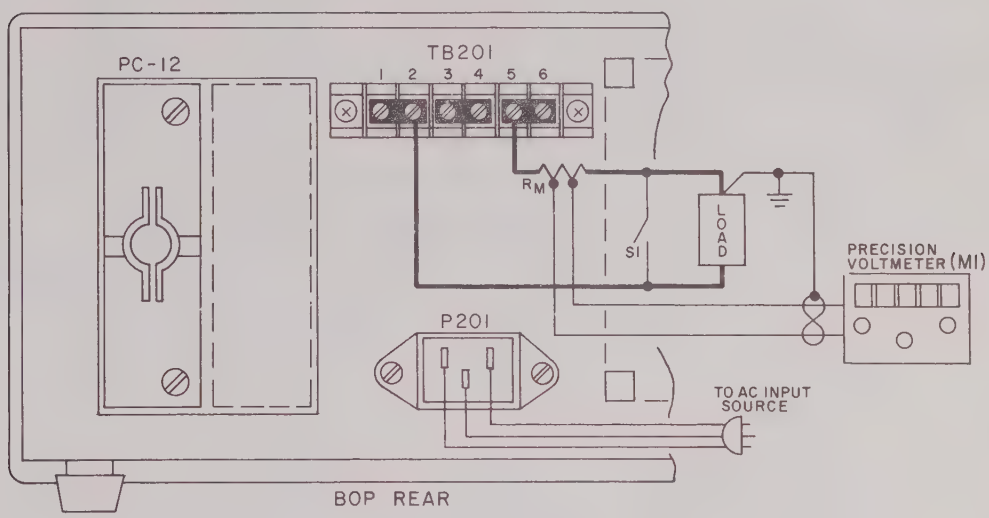


FIG. 5-5 OUTPUT EFFECT MEASUREMENTS, CURRENT CONTROL CHANNEL (TEST CIRCUIT).

5-21 OUTPUT EFFECT MEASUREMENTS, CURRENT CONTROL CHANNEL. The output effects due to a-c source or d-c load variations in the current mode can be measured with the circuit shown in FIG. 5-5. These output effects ("SOURCE EFFECT" and "LOAD EFFECT") are defined as the amount of output current change resulting from specified variations in the a-c source voltage, or from a change in load resistance (see Section I, Table 1-2). The output effects can be expressed as an absolute change (ΔI_o) or as a percentage of the total output current (I_o):

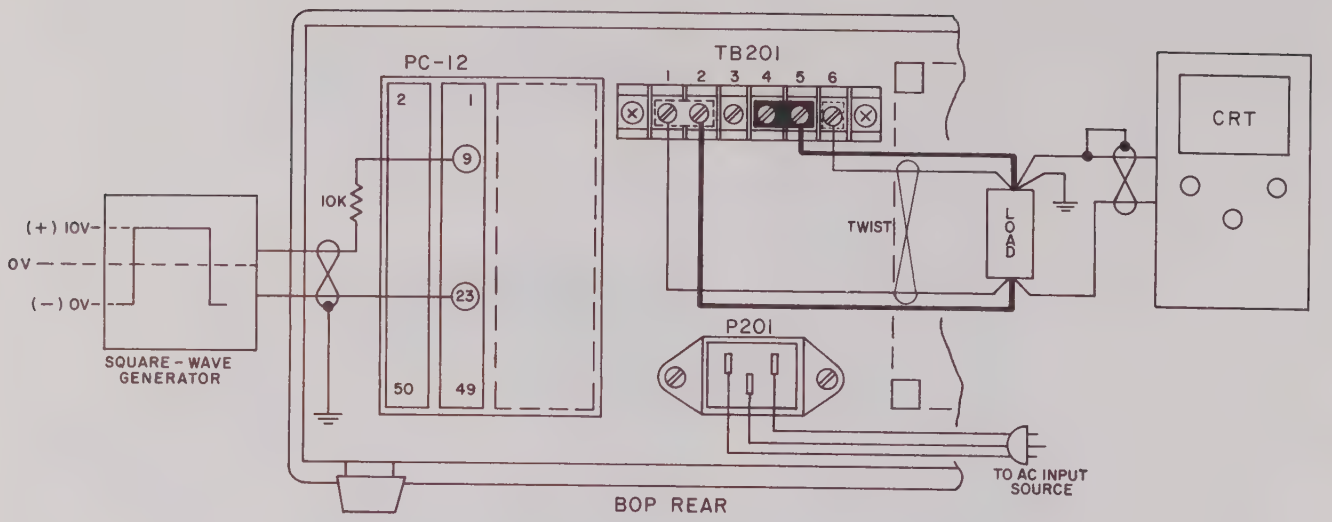
$$\% \text{ OUTPUT EFFECT} = \frac{\Delta I_o}{I_o} \times 100\% \quad \text{(Eq. 5-2).}$$

(Source or Load Effect)

where: ΔI_o = Change in output current
I_o = Total output current

5-22 PROCEDURE (Refer to FIG. 5-5)

1) Connect the BOP to a metered a-c input source, such as described in Paragraph 5-18A.
2) To measure the SOURCE EFFECT, vary the a-c source voltage over the specified range (105 to 125V or 210 to 250V) and note the deviation (ΔV divided by $R_M = \Delta I_o$) on the voltmeter (M1 across R_M).
3) To measure the LOAD EFFECT, close the load switch (S1) and note the deviation ($\Delta V/R_M$) on the voltmeter (M1 across R_M).
4) From the results of the two previous measurements, calculate the Source Effect and the Load Effect by means of equation (5-2). Note: $\Delta I_o = \Delta V/R_M$.



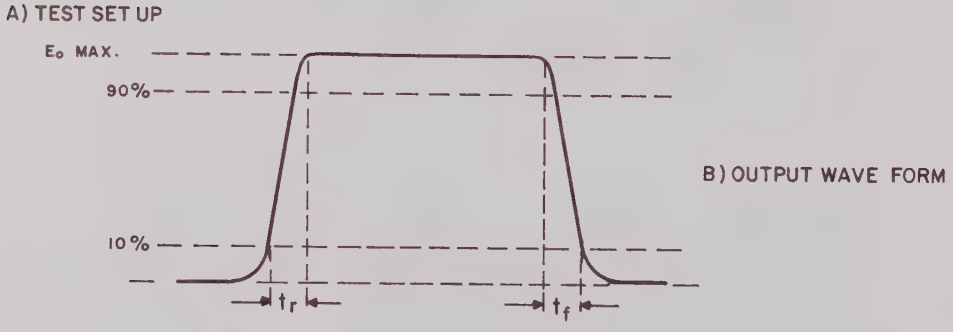


FIG. 5-6 MEASUREMENT OF THE RISE AND FALL TIME

5-23 DYNAMIC MEASUREMENTS. The verification of the specificaton for the RISE AND FALL TIME are excellent means of checking the dynamic performance of the BOP. In this test, the output voltage rise and fall time of the BOP is measured in response to a square wave input.

5-24 PROCEDURE (Refer to FIG. 5-6)

1) Connect the BOP and the external instrumentation as shown in FIG. 5-6. ***Note:*** The Signal Generator may be connected (without the 10KΩ resistor) to the BOP front panel VOLTAGE PROGRAMMING INPUT terminals.
2) Turn BOP "on". Adjust the gain of the SQUARE WAVE GENERATOR until the output wave form, displayed on the OSCILLOSCOPE shows a peak amplitude of E_o max, where "E_o max" is the maximum rated BOP output voltage.
3) Measure the rise and fall time of the displayed wave form from 10% to 90% of the displayed amplitude.

SECTION VI—ELECTRICAL PARTS LIST AND DIAGRAMS

6-1 GENERAL

6-2 This section contains the main schematic, the parts location diagrams, and a list of all replaceable electrical parts. All components are listed in alpha-numerical order of their reference designations. Consult your Kepco Representative for replacement of parts not listed here.

6-3 ORDERING INFORMATION

6-4 To order a replacement part or to inquire about parts not listed in the parts list, address order or inquiry either to your authorized Kepco Sales Representative or to:

KEPCO, INC.
131-38 Sanford Avenue
Flushing, N.Y. 11352

6-5 Specify the following information for each part:

a) Model and complete serial number of instrument.
b) Kepco part number.
c) Circuit reference designator.
d) Description.

6-6 To order a part not listed in the parts list, give a complete description and include its function and location.

NOTE: KEPCO DOES NOT STOCK OR SELL COMPLETE POWER SUPPLY SUBASSEMBLIES AS DESCRIBED HERE AND ELSEWHERE IN THIS INSTRUCTION MANUAL. SOME OF THE REASONS ARE LISTED BELOW:

1) Replacement of a complete subassembly is a comparatively rare necessity.
2) Kepco's subassemblies are readily serviceable, since most of them are the "plug-in" type.
2) All active components are socket mounted, making replacement extremely easy.
4) The nature of a closed-loop power supply system requires that subassembly replacement is followed by careful measurement of the total power supply performance. In addition, depending on the function of the subassembly, extensive aligment may required to restore power supply performnce to specified values.

IF REPAIRS INVOLVING SUBASSEMBLY REPLACEMENTS ARE REQUIRED, PLEASE CONSULT YOUR LOCAL KEPCO REPRESENTATIVE OR THE KEPCO SALES ENGINEERING DEPARTMENT IN FLUSHING, NEW YORK, N.Y.

ABBREVIATIONS USED IN KEPCO PARTS LISTS

A) Reference Designators:

A	= Assembly
B	= Blower (Fan)
C	= Capacitor
CB	= Circuit Breaker
CR	= Diode
DS	= Device, Signalling (Lamp)
F	= Fuse
FX	= Fuse Holder
IC	= Integrated Circuit
J	= Jack
K	= Relay
L	= Inductor
LC	= Light-Coupled Device
M	= Meter
P	= Plug
Q	= Transistor
R	= Resistor
S	= Switch
T	= Transformer
TB	= Terminal Block
V	= Vacuum Tube
X	= Socket

B) Descriptive Abbreviations

A	= Ampere
a-c	= Alternating Current
AMP	= Amplifier
AX	= Axial
CAP	= Capacitor
CER	= Ceramic
CT	= Center-Tap
°C	= Degree Centigrade
d-c	= Direct Current
DPDT	= Double Pole, Double Throw
DPST	= Double Pole, Single Throw
ELECT	= Electrolytic
F	= Farad
FILM	= Polyester Film
FLAM	= Flammable
FP	= Flame-Proof
°F	= Degree Fahrenheit
FXD	= Fixed
Ge	= Germanium
H	= Henry
Hz	= Hertz
IC	= Integrated Circuit
K	= Kilo (10^3)
m	= Milli (10^{-3})
M	= Mega (10^6)
MFR	= Manufacturer
MET	= Metal
n	= Nano (10^{-9})
NC	= Normally Closed
NO	= Normally Open
p	= Pico (10^{-12})
PC	= Printed Circuit
POT	= Potentiometer
PIV	= Peak Inverse Voltage
p-p	= Peak to Peak
ppm	= Parts Per Million
PWR	= Power
RAD	= Radial
RECT	= Rectifier
RECY	= Recovery
REG	= Regulated
RES	= Resistor
RMS	= Root Mean Square
Si	= Silicon
S-End	= Single Ended
SPDT	= Single Pole, Double Throw
SPST	= Single Pole, Single Throw
Stud Mt	= Stud Mounted
TAN	= Tantalum
TSTR	= Transistor
μ	= Micro (10^{-6})
V	= Volt
W	= Watt
WW	= Wire Wound

KEPCO® REPLACEMENT PARTS LIST

BOP 100-1M **CONTROL ASSEMBLY, A1** **Code 01-1487**

REFERENCE DESIGNATION	QTY.	DESCRIPTION	MFRS. NAME & PART NO. SEE BOTTOM NOTE	KEPCO PART NO.	REC. SPARE PART QTY.
C1,5	2	Cap., Elect., Ax. Leads 10KμF, 20%, 16V	United Chemi-Con Type KME	117-0978	1
C2,3	2	Cap., Elect., Ax. Leads 680μF, +50 – 10%, 40V	Mallory Type TT	117-0937	1
C4,9	2	Cap., Tantalum, Ax. Leads 1μF, 20%, 50V	Sprague Type 162D	117-0815	1
C6	1	Cap., Elect., Ax. Leads 3300μF, 20%, 16V	United Chemi-Con Series KMC	117-0986	1
C7,8	2	Cap., Elect., Ax. Leads 10μF, +50 – 10%, 25V	Mallory Type TT	117-0936	1
C10	1	Cap., Met., Film, Ax. Leads 4700pF, 10%, 200V	Westlake Type 32M	117-0588	1
C11	1	Cap., Film, Ax. Leads 0.01μF, 20%, 200V	Sprague Type 192P	117-0353	1
C12,13	2	Cap., Ceramic Disc 100pF, 10%, 500V	Murata GP5-101K	117-0754	1
C14	1	Cap., Ceramic Disc 22pF, 5%, 500V	Centralab DTN-22	117-0893	1
C17,18	2	Cap., Film, Ax. Leads 0.015μF, 10%, 200V	Westlake Series 150	117-0626	1
C19,20	2	Cap., Film, Ax. Leads 0.033μF, 10%, 200V	Westlake Series 150	117-0347	1
C21	1	Cap., Film, Ax. Leads 3300pF, 10% 200V	Mepco/Electra Type 708D1	117-0976	1
C22	1	Cap., Film, Ax. Leads 5600pF, 10%, 630V	Wesco Type 32M	117-0980	1
C24	1	Cap., Elect., Ax. Leads 100μF, 20%, 25V	United Chemi-Con Type KMC	117-0437	1
C25	1	Cap., Ceramic Disc 33pF, 10%, 1KV	Centralab DD-30	117-0679	1
C26	1	Cap., Ceramic Disc 5000pF, 20%, 500V	Sprague Type 562CZ5U	117-0061	1
C30,34	2	Cap., Monolithic Ceramic 0.1μF, 10%, 50V	Kemet Type C320C	117-0967	1
C31	1	Cap., Ceramic Disc 0.01μF, +80 – 20%, 50V	Centralab CK-103	117-0860	1
C35	1	Cap., Ceramic Disc 500pF, 10%, 500V	Murata GP5-501K	117-0755	1
CR1	1	Rectifier, Bridge 200V (PIV), 2A	Semicon Inc. Type FWLA200	124-0389	1
CR2,3	2	Rectifier, Bridge 200V (PIV), 1.5A	General Instruments Type W02M	124-0346	1
CR4	1	Thyristor, SCR 100V V_{RXM}, 4A, TO-220	Texas Instruments TIC106A	124-0496	1
CR5,63	2	Diode, Rect., Ax. Leads 100V (PIV), 1A	Semicon Inc. Type Si-1	124-0133	1
CR6,7	2	Diode, Zener, Ax. Leads 12V, 5%, 0.4W	Int. Rect. Corp. 1N963B	121-0058	1
CR8	1	Diode, Zener, Ax. Leads 6.2V, 5%, 0.4W	Motorola 1N827	121-0062	1
CR9 thru 57,59, 61,62,64,65,66	55	Diode, Switching, Ax. Leads 75V (PIV), 0.01A, 0.4W	AM Power Devices 1N4148	124-0437	12

6-3/6-4

NOTE: REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC

KEPCO® REPLACEMENT PARTS LIST

BOP 100-1M **CONTROL ASSEMBLY, A1** **Code 01-1487**

REFERENCE DESIGNATION	QTY.	DESCRIPTION	MFRS. NAME & PART NO. SEE BOTTOM NOTE	KEPCO PART NO.	REC. SPARE PART QTY.
CR58,60	2	Diode, Stabistor, Ax., Lds. 1.3V, 0.01A	AM Power Devices APD203	124-0435	1
IC1	1	IC, Voltage Regulator, Positive 15V, 0.5A, TO-220	Fairchild μA78M15UC	250-0064	1
IC2	1	IC, Voltage Regulator, Negative 15V, 0.5A, TO-220	Fairchild μA79M15AUC	250-0065	1
IC3	1	IC, Voltage Regulator, Positive 5V, 0.5A, TO-220	Fairchild μA78M05UC	250-0062	1
IC4,18	2	IC, Op. Amp. Dual 8 Pin, DIP, Plastic	Texas Instruments TL082CP	250-0107	1
IC5,6,10,11, 19,21,22	7	IC, Op. Amp. FET-Input 8 Pin, DIP, Plastic	Texas Instruments TL081CP	250-0100	1
IC7,8	2	IC, Op. Amp. Quad 14 Pin, DIP	National LM324N	250-0050	1
IC9	1	IC, Op. Amp. Quad 14 Pin, DIP, Plastic	Texas Instruments TL084ACN	250-0144	1
IC12	1	IC, Dual SPST CMOS Switch 14 Pin, DIP, Plastic	Analog Devices DG200CJ	250-0099	1
IC13	1	IC, Op. Amp. Dual 8 Pin, DIP, Plastic	Motorola MC1458P	250-0040	1
IC14	1	IC, Dual Comparator 8 Pin, DIP, Plastic	Texas Instruments LM393P	250-0098	1
IC15,16	2	IC, Quad 2-Input NAND Gate 14 Pin, DIP, Plastic	Texas Instruments SN74LS00N	250-0053	1
IC17	1	IC, Quad 2-Input NAND Gate 14 Pin, DIP, Plastic	Texas Instruments SN7400N	250-0038	1
IC20	1	IC, Op. Amp. 8 Pin, DIP, Plastic	Prec. Monolithics OP-37GP	250-0145	1
IC23	1	IC, Op. Amp. 8 Pin, DIP, Plastic	Prec. Monolithics OP-07CP	250-0146	1
LC1	1	IC, Opto- Coupler (Photo TRST) 6 Pin, DIP, Plastic	Kepco, Inc. 119-0106	119-0106	1
LC2	1	IC, Opto-Coupler (Photo Darlington) 6 Pin, DIP, Plastic	Gen. Inst. Corp. 4N33	119-0133	1
Q1,2,3	3	Transistor, Si, NPN Small Signal, TO-18	Texas Instruments 2N5450	119-0093	1
R1,3,5,33,34,35, 36,43,44,45,47,64, 65,66,67,93,94	17	Res., Fixed, Molded 1K ohm, 10%, ¼W	Allen Bradley CB1021	115-2238	4
R2	1	Res., Fixed, Molded 2.4K ohm, 5%, ¼W	Allen Bradley CB2425	115-2394	1
R4	1	Res., Fixed, Molded 470 ohm, 10%, ½W	Allen Bradley EB4711	115-0608	1
R6,19	2	Res., Fixed, Molded 180 ohm, 10%, ¼W	Allen Bradley CB1811	115-2385	1
R7,21,95	3	Res., Fixed, Molded 5.6K ohm, 10%, ¼W	Allen Bradley CB5621	115-2491	1
R8,9,23,24,28,37, 38,72,74,76,77, 78,79,80,82,13A	16	Res., Fixed, Metal Film 10K ohm, 1%, 1/8W	Dale Type RN55D	115-2174	4
R10,14,97	3	Res., Fixed, Molded 330 ohm, 10%, ¼W	Allen Bradley CB3311	115-2233	1

6-5/6-6

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KEPCO® REPLACEMENT PARTS LIST

BOP 100-1M **CONTROL ASSEMBLY, A1** **Code 01-1487**

REFERENCE DESIGNATION	QTY.	DESCRIPTION	MFRS. NAME & PART NO. SEE BOTTOM NOTE	KEPCO PART NO.	REC. SPARE PART QTY.
R11,12	2	Res., Fixed, Metal Film 9.53K ohm, 1%, 1/8W	Dale Type RN55D	115-2686	1
R13	1	Res., Fixed, Metal Film 30.1K ohm, 1%, 1/4W	Dale Type RN60D	115-1461	1
R15	1	Res., Fixed, Molded 1.1M ohm, 5%, 1/4W	Allen Bradley CB1155	115-2657	1
R16	1	Res., Fixed, Metal Film 24.3K ohm, 1%, 1/8W	Dale Type RN55D	115-2451	1
R17,68,69,70, 98,10A,11A,17A	8	Res., Fixed, Molded 10 ohm, 10%, 1/4W	Allen Bradley CB1001	115-2230	1
R18,27,75	3	Res., Fixed, Metal Film 1K ohm, 1%, 1/8W	Dale Type RN55D	115-2180	1
R20	1	Res., Fixed, Metal Film 511 ohm, 1%, 1/8W	Dale Type RN55D	115-2260	1
R22	1	Res., Fixed, Metal Film 8.66K ohm, 1%, 1/8W	Dale Type RN55D	115-2511	1
R25	1	Res., Fixed, Metal Film 4.32K ohm, 1%, 1/8W	Dale Type RN55D	115-2539	1
R26	1	Res., Fixed, Metal Film 8.06K ohm, 1%, 1/8W	Dale Type RN55D	115-2445	1
R29	1	Res., Fixed, Metal Film 3.01K ohm, 1% 1/8W	Dale Type RN55D	115-2214	1
R30	1	Res., Fixed, Metal Film 5.76K ohm, 1%, 1/8W	Dale Type RN55D	115-2222	1
R31,32	2	Res., Var., Cermet, Trim. 1K ohm, 10%, 1.25W	Bourns Type 3009P	115-2456	1
R39,40	2	Res., Fixed, Molded 2.7M ohm, 5%, 1/4W	Allen Bradley CB2755	115-2602	1
R41,42,81,83	4	Res., Var., Cermet, Trim. 100K ohm, 10%, 1.25W	Bourns Type 3009P	115-2399	1
R46,48,53,54	4	Res., Fixed, Metal Film 57.6K ohm, 1%, 1/8W	Dale Type RN55D	115-2466	1
R49,52	2	Res., Fixed, Metal Film 15K ohm, 1%, 1/8W	Dale Type RN55D	115-2452	1
R50	1	Res., Var., Cermet, Trim. 10K ohm, 10%, 1W	Bourns Type 3005P	115-2266	1
R51,55	2	Res., Fixed, Metal Film 750 ohm, 1%, 1/8W	Dale Type RN55D	115-2259	1
R56 thru 59,96, 8A,9A	7	Res., Fixed, Molded 10K ohm, 10%, 1/4W	Allen Bradley CB1031	115-2211	1
R60,63	2	Res., Fixed, Metal Film 2.74K ohm, 1%, 1/8W	Dale Type RN55D	115-2439	1
R61,62	2	Res., Fixed, Metal Film 1.1K ohm, 1%, 1/8W	Dale Type RN55D	115-2176	1
R71	1	Res., Fixed, Metal Film 9.31K ohm, 1%, 1/8W	Dale Type RN55D	115-2553	1
R73	1	Res., Fixed, Metal Film 9.09K ohm, 1%, 1/8W	Dale Type RN55D	115-2678	1
R84	1	Res., Fixed, Molded 5.1K ohm, 5%, 1/2W	Allen Bradley EB5125	115-1659	1
R85 thru 90	6	Res., Fixed, Molded 22K ohm, 10%, 1/4W	Allen Bradley CB2231	115-2458	1

6-7/6-8

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KEPCO® REPLACEMENT PARTS LIST

BOP 100-1M **CONTROL ASSEMBLY, A1** **Code 01-1487**

REFERENCE DESIGNATION	QTY.	DESCRIPTION	MFRS. NAME & PART NO. SEE BOTTOM NOTE	KEPCO PART NO.	REC. SPARE PART QTY.
R91	1	Res., Fixed, Molded 10 ohm, 5%, ¼W	Allen Bradley CB1005	115-2643	1
R92	1	Res., Fixed, Carbon Film 510K ohm, 5%, ¼W	TRW Type CF-¼	115-2728	1
R99,1A,2A,3A	4	Res., Fixed, Molded 3.3K ohm, 10%, ¼W	Allen Bradley CB3321	115-2257	1
R4A thru 7A	4	Res., Fixed, Molded 750K ohm, 5%, ¼W	Allen Bradley CB7545	115-2661	1
R18A	1	Res., Fixed, Molded 6.2K ohm, 5%, ¼W	Allen Bradley CB3321	115-2258	1
RN1	1	Res., Network, SIP. 5.6K ohm, 5%, 7 units, 1W	Sprague Type 216	234-0004	1
RN2,3	2	Res., Matched Pair 90K/10K ohm, 0.01% match	Kepco, Inc. 234-0020	234-0020	1

NOTE: REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION

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KEPCO® REPLACEMENT PARTS LIST

BOP 100-1M **FRONT PANEL ASSEMBLY, PART OF A2** **Code 04-0881**

REFERENCE DESIGNATION	QTY.	DESCRIPTION	MFRS. NAME & PART NO. SEE BOTTOM NOTE	KEPCO PART NO.	REC. SPARE PART QTY.
C101,102	2	Cap., Mylar, Axial Leads 0.5μF, 10%, 200V	TRW Type X663F	117-0123	1
CB101	1	Circuit Breaker 2 Pole, 2 CKT	Heineman Electronics 127-0355	127-0353	1
DS101,102 103,104	4	Panel Light, LED 6V d-c, 20-mA, Red	Dialco Type 507	152-0092	1
DS105	1	Panel Light, LED 6V, 20-mA, Green	Littelfuse Series 900	152-0097	1
M101	1	Meter, 1-0-1A d-c Center Zero	Jewell Instruments 135-0535	135-0535	1
M102	1	Meter, 100-0-100V d-c Center Zero	Jewell Instruments 135-0538	135-0538	1
R101 thru 104	4	Res., Var., Cermet 10K ohm, 10%, 2W	Allen Bradley Type 70	115-2612	1
R105,106	2	Res., Var., Wire-Bound 20K ohm, 5%, 2W	TRW Type 8400	115-1224	1
S101,102, 103	3	Switch, Toggle DPDT, 250V-5A (AC)	Carling Switch SGD0410-PR-B	127-0325	1

MISCELLANEOUS MECHANICAL PARTS

N.A.	4	Binding Post, Red	E.F. Johnson No. 111-102	151-0025	1
N.A.	4	Binding Post, Black	E.F. Johnson No. 111-103	151-0026	1
N.A.	1	Binding Post, Green	E.F. Johnson No. 111-104	151-0048	1
N.A.	2	Control Knob	Alco No. PKA-50B-¼	155-0052	1
N.A.	5	Clip For Panel Lights	Dialco No. 515-0051	102-0107	1
P201	1	AC Power Receptacle	Switchcraft No. EAC-302	143-0290	1
N.A.	4	Bottom Foot	Goodyear Sundries ½ x ¾-No. 8 Screw	158-0003	1
TB201	1	Barrier Strip Assembly	Kepco Inc. P/N 167-0883	167-0883	1
N.A.	1	AC Power Line Cord	Belden No. 118-0557	118-0557	1
PC-12	1	Programming Connector	Kepco Model PC-12- (not wired)	N.A.	1

NOTE: REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

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KEPCO® REPLACEMENT PARTS LIST

BOP 100-1M **CHASSIS ASSEMBLY, A2** **Code 04-0881**

REFERENCE DESIGNATION	QTY.	DESCRIPTION	MFRS. NAME & PART NO. SEE BOTTOM NOTE	KEPCO PART NO.	REC. SPARE PART QTY.
B201	1	Fan Motor 50/60 Hz, 115V a-c	Howard Industries 148-0027	148-0027	1
N.A.	1	Fan Blade	Howard Industries 149-0023	149-0023	1
C201,202	2	Cap., Elect., Can-Type 1.85KμF, +50-10%, 200V	Mepco/Electra Type 86F	117-0895	1
C203	1	Cap., Mylar, Axial Leads 0.1μF, 20%, 600V	TRW Type X663F	117-0316	1
C204,205 206,207	4	Cap., Ceramic Disc. 0.02μF, 20%, 1KV	Radio Mat. Corp. Type B	117-0104	1
CR201	1	Rectifier Bridge 400V (PIV), 6A	Semicon SBR-6A4	124-0396	1
R201,202	2	Res., Fixed, Molded 18K ohm, 10%, 2W	Allen Bradley HB1831	115-2682	1
R203	1	Res., Fixed, Molded 10 ohm, 10%, ¼W	TRW Type GBT-¼	115-2230	1
T201	1	Transformer, Power	Kepco, Inc. 100-2174	100-2174	1
T202	1	Transformer, Auxiliary	Kepco Inc. No. 100-2167	100-2167	1

NOTE: REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

BOP 100-1M **DRIVER ASSEMBLY, A3** **Code 02-2186**

REFERENCE DESIGNATION	QTY.	DESCRIPTION	MFRS. NAME & PART NO. SEE BOTTOM NOTE	KEPCO PART NO.	REC. SPARE PART QTY.
C301,302	2	Cap., Ceramic Disc. 500pF, 10%, 500V	Radio Material Corp. Type JF	117-0755	1
CR301,302	2	Diode, Switching, Ax. Leads 75V (PIV), 1A, 0.4W	AM Power Devices 1N4148	124-0437	1
CR303,304	2	Diode, Rect., Axial Leads 400V (PIV), 5A	Semicon Inc. Type S-5A4	124-0348	1
CR305,306	2	Diode, Zener, Axial Leads 6.8V, 5%, 0.5V	Motorola IN5235B	121-0080	1
Q301	1	Transistor, Si., NPN Med. Power, TO-220	Texas Instruments TIP100	119-0127	1
Q302	1	Transistor, Si PNP Med. Power, TO-220	Texas Instruments TIP105	119-0126	1
Q303	1	Transistor, Si, NPN Hi Power, TO-3	Kepco, Inc. 119-0091	119-0091	1
Q304	1	Transistor, Si, PNP Hi Power, TO-3	Motorola 2N6609	119-0128	1
Q305	1	Transistor, Si, NPN Lo Power, TO-5	Kepco, Inc. 119-0118	119-0118	1
Q306	1	Transistor, Si, PNP Lo Power, TO-39	Motorola 2N5415	119-0132	1
R301	1	Res., Fxd, Wire-Wound, Ax., Lds 0.5 ohm, 1%, 5W	Tepro Type TSK-5	115-2198	1
R302,303	2	Res., Fxd, Wire-Wound, Ax., Lds 0.4 ohm, 3%, 3W	Tepro Type TS3	115-2462	1
R304,305	2	Res., Fixed, Molded 1K ohm, 10%, ¼W	Allen Bradley CB1021	115-2238	1
R306,307 308,309	4	Res., Fixed, Molded 22K ohm, 5%, 2W	Allen Bradley HB2235	115-0229	1
R312,313	2	Res., Fixed, Molded 20 ohm, 5%, ½W	Allen Bradley EB2005	115-0508	1

NOTE REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.

KEPCO® REPLACEMENT PARTS LIST

BOP 100-1M **HEAT SINK ASSEMBLY, A4** **Code 04-0881**

REFERENCE DESIGNATION	QTY.	DESCRIPTION	MFRS. NAME & PART NO. SEE BOTTOM NOTE	KEPCO PART NO.	REC. SPARE PART QTY.
Q401,402 403,404	4	Transistor, Si, NPN Power, TO-3	Solid Power 119-0091	119-0091	1
Q407,408, 409,410	4	Transistor, Si, PNP Power, TO-3	Motorola 2N6609	119-0128	1
R401,402,403 404,407,408 409,410	8	Res., Fxd, Wire-Wound, Ax. Lds. 1.2 ohms, 3%, 3W	Tepro Type TS-3W	115-2136	1
R413,414 415,416	4	Res., Fixed, Molded 100 ohms 10%, ¼W	TRW Type GBT-¼	115-2231	1
S401	1	Switch, Thermostat N.O., 260°F ± 10°F, ΔF = 30°	Stemco A510	127-0248	1

NOTE: REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

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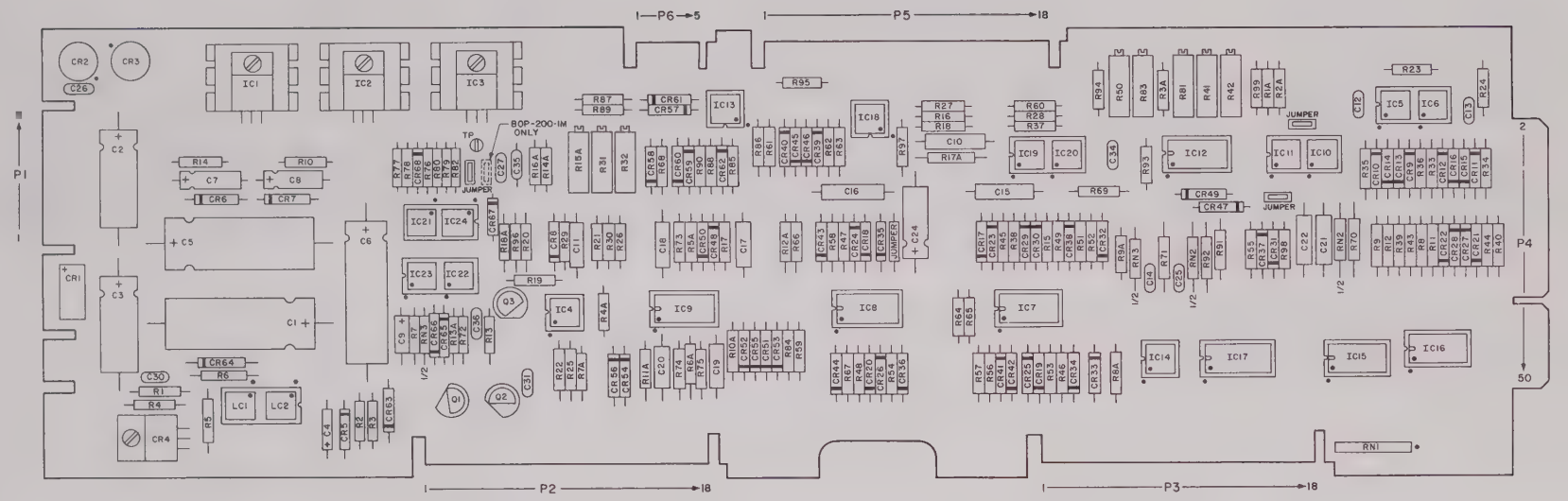
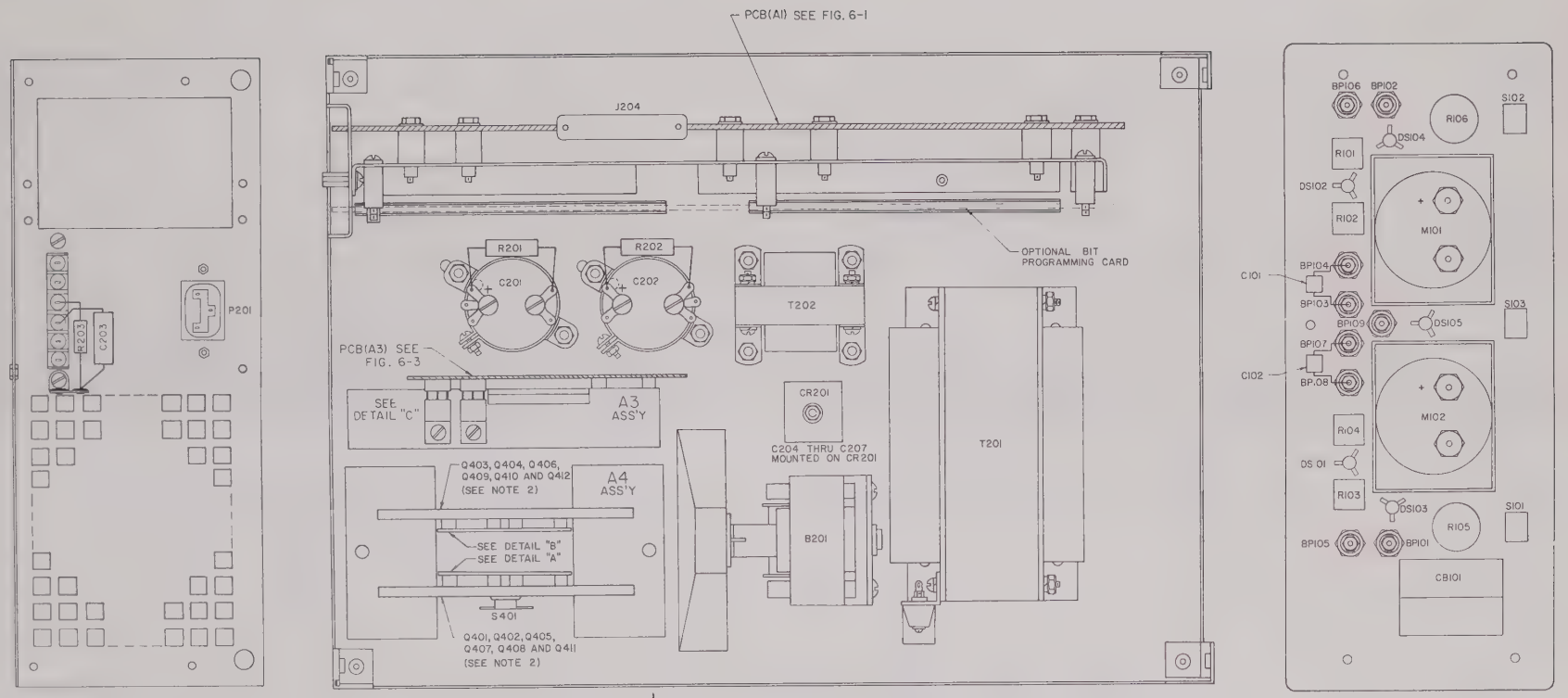
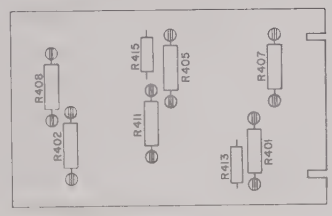


NOTE: NOT ALL COMPONENTS USED IN ALL MODELS, SEE PARTS LIST.

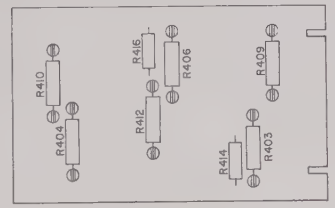
FIG. 6-1 COMPONENT LOCATION, CONTROL ASSEMBLY (A1).





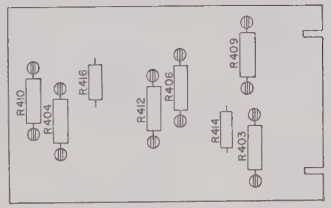
DETAIL "A"

NOTE: 1. THIS DRAWING IS USED FOR MODELS: BOP 20-10M, BOP 36-6M, BOP 50-2M, BOP 50-4M, BOP 72-3M, BOP 100-1M AND BOP 100-2M.
2. NOT ALL COMPONENTS USED IN ALL MODELS, SEE PARTS LIST.

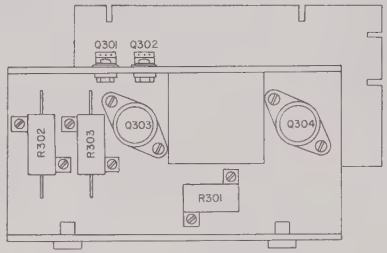


DETAIL "B"

NOTE: 1. THIS DRAWING IS USED FOR MODELS: BOP 20-10M, BOP 36-6M, BOP 50-2M AND BOP 50-4M.
2. NOT ALL COMPONENTS USED IN ALL MODELS, SEE PARTS LIST.



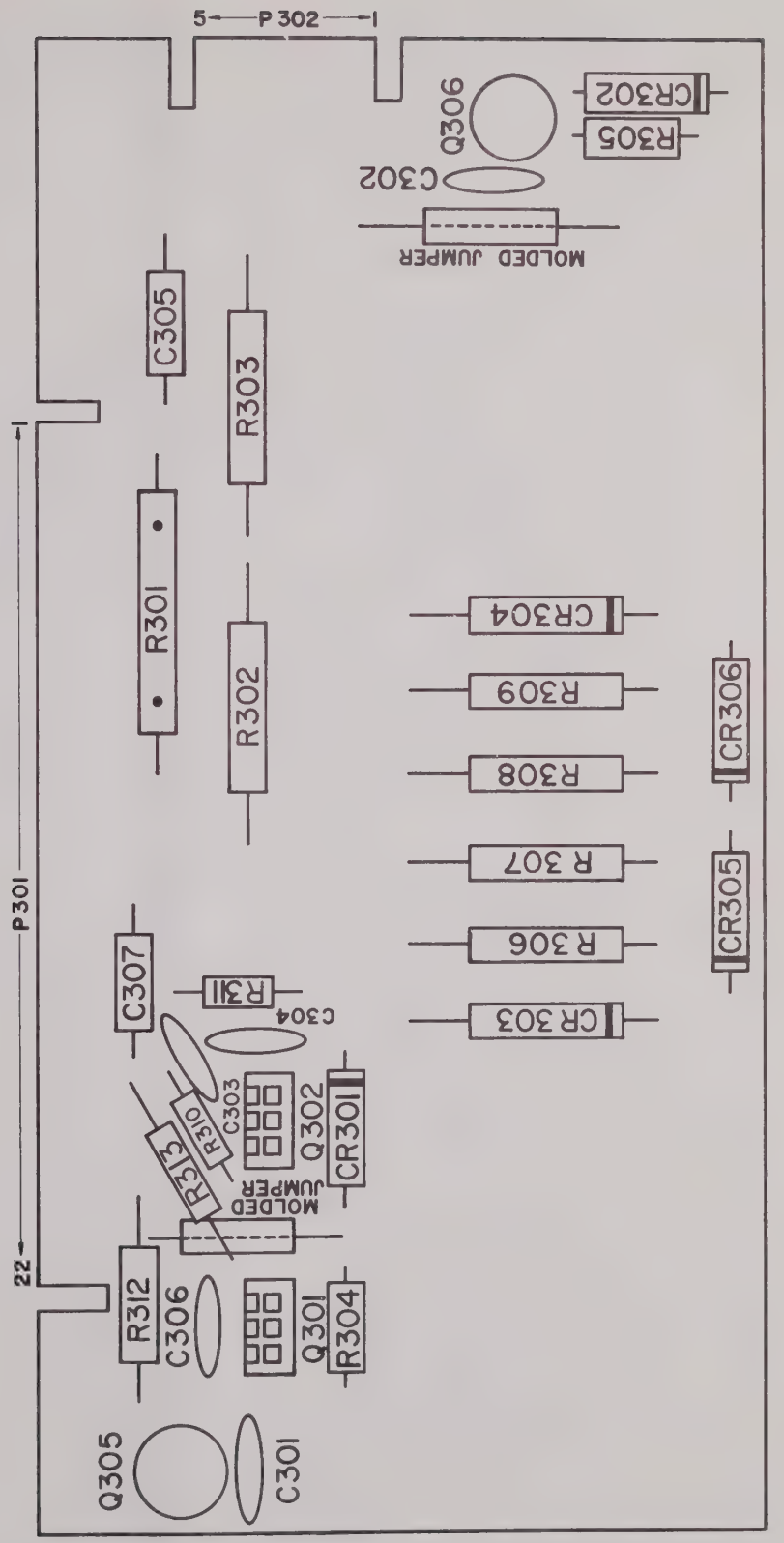
NOTE: 1. THIS DRAWING IS USED FOR MODELS: BOP 72-3M, BOP 100-1M AND BOP 100-2M.
2. NOT ALL COMPONENTS USED IN ALL MODELS, SEE PARTS LIST.



DETAIL "C"
SEE NOTE

NOTE: NOT ALL COMPONENTS USED IN ALL MODELS SEE PART LIST.

FIG. 6-2 COMPONENT LOCATION, MAIN CHASSIS ASSEMBLY (A2) AND HEAT SINK ASSEMBLY (A4, A5).



NOTE: NOT ALL COMPONENTS USED IN ALL MODELS, SEE PARTS LIST.

FIG. 6-3 COMPONENT LOCATION, DRIVER ASS'Y. (A3).

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PATENT NOTICE: Applicable Patent Numbers will be supplied on request.

NOTES:
1 RESISTOR VALUES IN OHMS, K=10^3, M=10^6
2 CAPACITOR VALUES IN MICROFARADS, EXCEPT AS NOTED
3 VOLTAGE READINGS ARE NOMINAL VALUES, AT 115 VAC INPUT, NO LOAD
4 TRANSFORMER CONNECTIONS SHOWN ARE FOR 115 VAC OPERATION; SEE INSTRUCTION MANUAL SECTION II, FOR OPERATION ON OTHER INPUT SOURCES
5 NOT ALL COMPONENTS IN ALL MODELS FOR VALUES OF COMPONENTS MARKED "Δ" SEE PARTS LIST
6 CONNECTIONS NOT SHOWN:

COMPONENT	PIN NO TO +15V	PIN NO TO −15V	PIN NO TO 0V	PIN NO TO +5V
IC4	8	4	——	——
IC5	7	4	——	——
IC6	7	4	——	——
IC7	4	11	——	——
IC8	4	11	——	——
IC9	4	11	——	——
IC10	7	4	——	——
IC11	7	4	——	——
IC12	12	7	3	——
IC13	8	4	——	——
IC14	8	——	4	——
IC15	——	——	7	14
IC16	——	——	7	14
IC17	——	——	7	14
IC18	8	——	——	——
IC19	7	4	——	——
IC20	7	4	——	——
IC21	7	4	——	——
IC22	7	4	——	——
IC23	7	4	——	——
IC24	7	4	——	——

7 ▽ SC = SENSING COMMON
▽ 0V = COMMON (0V)
8 WINDINGS (WD) "A" AND "B" ON T201 USED ON 200V BOP MODELS ONLY
9 CONNECTIONS "X1"-"X2" AND "Y1"-"Y2" ON CB101, USED ON ALL BOP MODELS, EXCEPT 200V MODELS
10 JUMPER (DASHED) BOP 200 ONLY
JUMPER (SOLID) ALL OTHER BOP MODELS
11 PINS 21, 43, 44, 45, 46, 48 & 50 ON REAR PROGRAMMING CONNECTOR (P4/PC-12) ARE NOT USED
12 JUMPERS ARE CONNECTED IN ALL MODELS THERE FUNCTIONS ARE ONLY FOR TESTING PURPOSES

DRIVER ASSEMBLY A3
AND
HEATSINK ASSEMBLY A4, A5 Δ

SEE FIG. 6-4 (PART II) FOR DETAILS

A2 SEE NOTE 8

A1 CONTROL ASSEMBLY

FIG. 6-4 (PART I) MAIN SCHEMATIC DIAGRAM, BOP ¾ AND BOP (400W) FULL RACK SERIES.

EM17260/1-1487

6-23/6-24

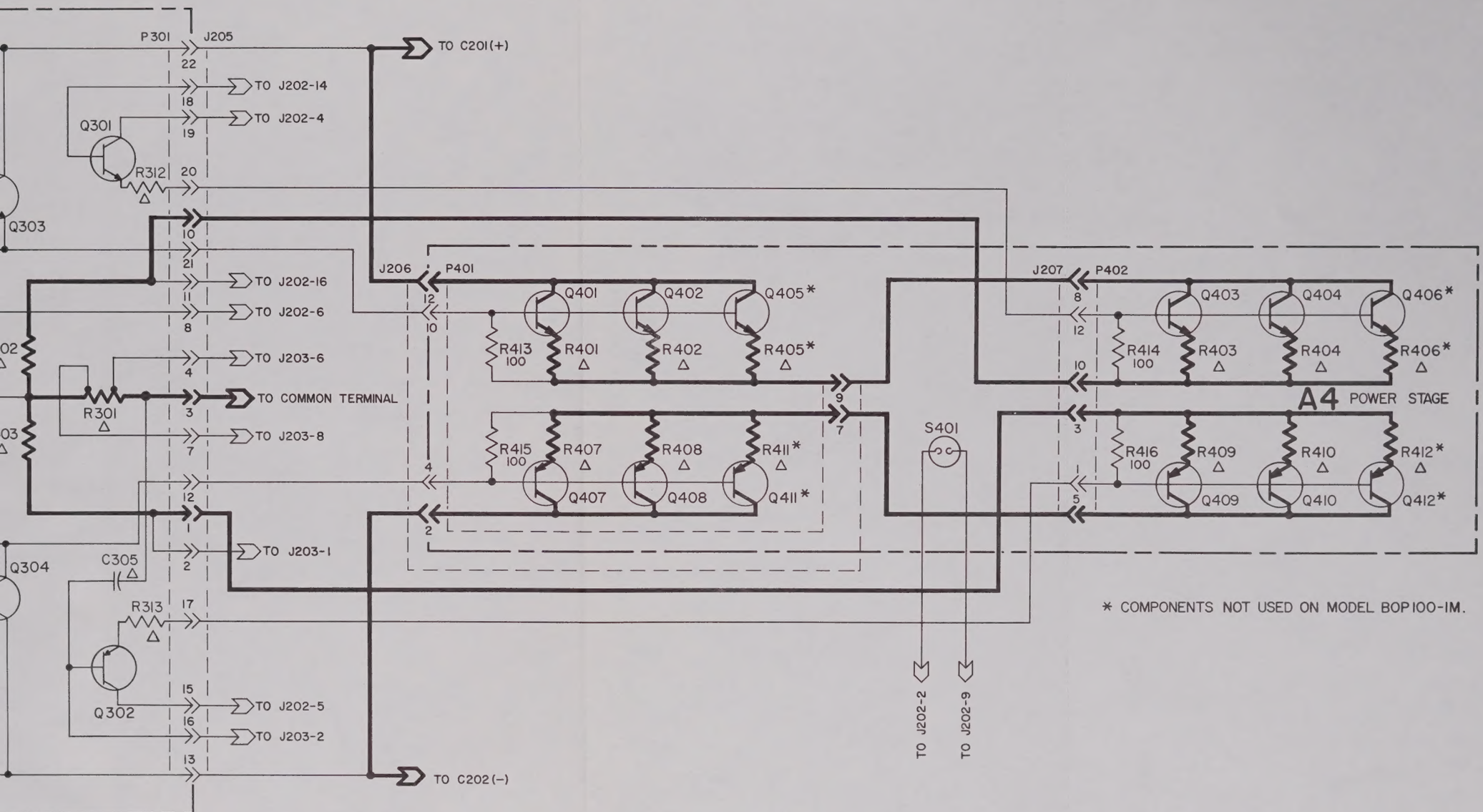

FIG. 6-4 (PART II) MAIN SCHEMATIC DIAGRAM, MODEL BOP 72-3M, BOP 100-1M AND BOP 100-2M.

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INSTRUCTION MANUAL CORRECTION

Please note the following corrections to the Manual Material as indicated:

Parts List and Schematic Diagram:

1. Change:	C22	Cap.,Film,Ax. Leads	0.01uF,10%,200V	Kepco #117-0983
to:	C22	Cap.,Film,Ax. Leads	5600pF,10%,630V	Kepco #117-0980
2. Change:	C17,18	Cap.,Film,Ax. Leads	4700pF,10%,200V	Kepco #117-0588
to:	C17,18	Cap.,Film,Ax. Leads	0.015uF,10%,200V	Kepco #117-0626
3. Change:	C19,20	Cap.,Film,Ax. Leads	0.01uF,20%,200V	Kepco #117-0353
to:	C19,20	Cap.,Film,Ax. Leads	0.033uF,10%,200V	Kepco #117-0347
4. Delete:	C15	Cap.,Ceramic Disc.	150pF,10%,500V	Kepco #117-0977
5. Add:	C34	Cap.,Ceramic Disc.	0.1uF,10%,50V	Kepco #117-0967

Note: C34 has been added to assembly A1. It is connected to IC 20, between Pins 4 and 7.

6. Add:	C35	Cap.,Ceramic Disc.	500pF,10%,500V	Kepco #117-0755
7. Add:	R18A	Res.,Fxd.,Molded	6.2K ohm,5%,¼W	Kepco #115-2258

Note: C35 and R18A have been added to assembly A1. They are connected in series, between IC 22-Pin 3 and ØV.

8. Change:	C6	Cap.,Elect.,Ax.Leads	2200uF,+50,-10%,15V	Kepco #117-0918
To:	C6	Cap.,Elect.,Ax.Leads	3300uF,±20%,16V	Kepco #117-0986

BOP 100-1M/07-3186/r18 C5715
BOP 100-1M/11-1986/r19 C5781

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